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A COMPUTER PROGRAM FOR PROCESSING IMPEDANCE CARDIOGRAPHIC DATA: IMPROVING ACCURACY THROUGH USER-INTERACTIVE SOFTWARE

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SUMMARY

This report contains the source code and documentation for a computer program used to process impedance cardiography data. The cardiodynamic measures derived from impedance cardiography are ventricular stroke volume, cardiac output, cardiac index and Heather index. The program digitizes data collected from the Minnesota Impedance Cardiograph, electrocardiography (ECG), and respiratory cycles and then stores these data on hard disk. It computes the cardiodynamic functions using interactive graphics and stores the means and standard deviations of each 15-second data epoch on floppy disk. This software was designed on a Digital PRO380 microcomputer and used version 2.0 of P/OS, with (minimally) a 4-channel 16 bit analog/digital (A/D) converter. Applications software is written in Fortran 77, and uses Digital's Pro-tool Kit Real Time Interface Library (PRTIL), CORE Graphic Library (CGL), and laboratory routines. Source code can be readily modified to accommodate alternative detection, A/D conversion and interactive graphics. The object code utilizing overlays and multitasking has a maximum of 50 Kbytes.

INTRODUCTION

The Psychophysiological Research Laboratory of the Neurosciences Branch at NASA Ames Research Center has been engaged in a series of ground-based investigations of human autonomic responses to motion sickness. With the final goal of developing a treatment for the motion sickness-like symptoms which affect astronauts exposed to the microgravity environment of space, our group uses noninvasive electrophysiological measures to document changes in physiological activity levels in different subject populations. In the course of this research, we have found that measures of cardiovascular function are very sensitive indices of the malaise levels experienced by test participants. In previous studies (ref. 1), it was observed that high-susceptibility subjects tended to produce more labile and larger magnitude changes in heart rate and blood volume pulse (a relative measure of peripheral resistance), when exposed to motion sickness stressors than low-susceptibility subjects. We decided to investigate this result further.

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Although electrocardiography (ECG) provides excellent information regarding the electrical function of the heart muscle, it gives no definitive information regarding physical function. Heart rate alone is insufficient for determining the level of sympathetic influence on cardiac muscle. An increase in heart rate can be caused by either an increase in sympathetic tone or a decrease in parasympathic activation. Finger pulse volume, although easy to monitor, is not as reliable an index of sympathetic tone of the vasomusculature as total peripheral resistance, which is derived from both blood pressure and cardiac output (ref. 2).

We needed a noninvasive, atraumatic means of examining human cardiodynamics in a motion-sickness inducing environment. Our assessment of impedance cardiography is that it provides relatively accurate data on a wide range of dynamic cardiovascular variables and appears even to be sensitive to rapid changes in these variables. Impedance cardiography techniques enable the measurement of myocardial contractility, (heather index) which is directly related to the level of sympathetic innervation of the heart. Even when there is no apparent change in heart rate, changes in stroke volume or myocardial contractility may be occurring which reflect significant differences in autonomic function (refs. 2,3). Other valuable information obtained from this device include cardiac output and central volume (transthoracic impedance).

Miller and Horvath (ref. 3) describe the advantages and drawbacks of impedance cardiography and compare the accuracy of this technique to other invasive and noninvasive measures of cardiodynamics. The principal disadvantage is that erroneous results may be produced if the user is unfamiliar with the effects of artifact on the computation of specific data epochs and is not careful to select cardiac cycles (dZ/dT peaks) that occur only during the expiratory pause between breaths. The Minnesota Impedance Cardiograph, manufactured by Instrumentation for Medicine, Inc., Greenwich, Conn., is available with a (firmware only) microprocessor which is designed to automate this process. However, we found that with the microprocessor, one can obtain data from one heartbeat at a minimum of 8-sec intervals. Thus much data are lost from the intervening beats, especially when rapid changes are occurring in the cardiovascular system.

This paper contains the source code and operator's instructions for a user-interactive program written in support of our research. The program provides more accurate calculations of cardiac parameters based on a greater quantity of data. The sampling rate for digitizing data is 200 samples/sec; the data can be sampled at twice real-time speed from analog tape. The collected data consist of the first derivative of pulsatile thoracic impedance change (dZ/dt), basal impedance, electrocardiogram, and respiration waveforms. During an interactive graphics session, data for dZ/dt, ECG and chest respiration are displayed on a monitor in 15-sec epochs. The user can select from the screen the dZ/dt peaks that are used to calculate cardiodynamic functions. The program computes and stores the means and standard deviations for the cardiac measures for each 15-sec epoch.

CALCULATIONS PERFORMED:

$$\text{Stroke Volume} = \frac{PL^2\ T(dZ/dt)min}{Zo^2}$$

$$P = 53.2\ e^{(0.002)(\text{Hematocrit})}$$

Expressed in ohms-cm

e = 2.7183 the natural exponent

Hematocrit expressed in units of percent

L = distance between two inner electrodes in cm

Zo = Transthoracic Impedance expressed in ohms

Cardiac Output = (Stroke Volume)(Pulse rate)/1000

Expressed in liters per min

Pulse rate is expressed in beats per min

Cardiac Index = Cardiac Output/Body Surface Area

Expressed in liters per min

Body surface area = H x W x 0.007184

Expressed in m^2

H = height in cm

W = weight in Kg

Heather Index = $(dZ/dt)min/R\text{-}Z$

Expressed in ohms per sec^2

R-Z = interval between the R-wave of the ECG and

the peak of dZ/dt expressed in sec

REQUIRED HARDWARE AND SUBJECT INFORMATION

Hardware for this research includes a Minnesota Impedance Cardiograph, a respiration transducer (e.g., a piezoelectric or mercury strain gage) and a preamplifier capable of producing an analog output signal of respiratory responses, electrocardiography equipment (either the Minnesota Impedance cardiograph for direct measurement or an ECG amplifier for external measurement), a Digital PRO380 microcomputer which uses version 2.0 of P/OS, and a four-channel A/D converter (16-bit). Applications software, written in Fortran 77, uses Digital's Pro-tool Kit Real Time Interface Library (PRTIL), CORE Graphic Library (CGL), and laboratory routines. Source code can be readily modified to accommodate alternative routines for peak detection, A/D conversion and interactive graphics. The object code uses overlays and multitasking and has a maximum of 50 Kbytes.

Additional subject information required to implement this software is (a) hematocrit count; (b) weight in Kg; (c) height in cm; and (d) the distance between the two inner impedance cardiography electrodes (tapes), measured both in front and back and then averaged.

This software is installed on a DEC PRO 380 computer by following applications installation instructions in Professional Developer's Toolkit Reference Manual, Chapters 3 and 6.

Three options will appear on the screen:

```
**************************************
*
*  SELECT FROM THE FOLLOWING
*
*  1. DIGITIZE A DATA FILE FROM TAPE
*
*  2. DATA REDUCTION OF DIGITIZED FILE
*
*  3. EXIT
*
**************************************

[ENTER 1, 2, OR 3]:
```

Procedure for digitizing a tape data file--SELECTION 1. If the user selects option 1, the following displays appear on the screen:

```
**************************************

        DIGITIZING A DATA FILE

**************************************
```

PLEASE ENTER RUN ID FOR THIS FILE:

1. User enters an ID of 6 digits.

PLEASE ENTER RUN TIME (IN SECS.) FOR TAPE FILE:

2. Determine maximum duration of data file in seconds (e.g. 30 minutes=1800 seconds); ADD 60 seconds to run length (e.g , 1860). ENTER THIS NUMBER. NOTE: an additional 60 seconds is added to the file length to accommodate acquisition of calibration data.

```
HOW FAST TO SAMPLE THE DATA ON TAPE?

    ENTER 1 FOR REAL-TIME

    ENTER 2 FOR TWICE REAL TIME

[ENTER 1 OR 2]:
```

3. The option of digitizing data at twice real-time is determined by the memory capacity (512 K RAM) and the I/O response time (less then 0.025 sec) of the system implementing this program. This I/O response time is required to store four-channels of data, in two-byte segments. After entering 1 or 2, the screen displays:

HIT "S" TO START, "P" TO PAUSE, OR "A" TO ABORT:

FOLLOWED BY A [RETURN]

4. Position analog tape to beginning of run, then press the keys "S" and "Return" to begin computer acquisition of high calibration data. Data aquisition may be paused at any time by pressing the key "P" and will not continue until the user presses the "RESUME" key. Acquisition may be aborted at any time by pressing the key "A", at which time the program prompts to the user to either SAVE or DELETE the created digitized file. If the user has chosen to start data acquisition (i.e., have pressed the key "S"), the screen will display a flashing message and three columns will scroll continuously until acquisition ends. The first column indicates the active buffer (switches between buffers 1 and 2). The second column indicates error status (e.g., if A/D is turned off). No error is indicated by "0". The third column displays the data second currently being acquired.

```
**********************************

* DATA ACQUISITION IN PROGRESS *

**********************************

      1        0        1
      1        0        1
      1        0        1
      1        0        1
      1        0        1
      2        0        2
      2        0        2
      2        0        2
      :        :        :
      1        0       30
      1        0       30
      1        0       30

IMPACQ -- PAUSE - ADVANCE TAPE TO START OF LOW CALS NOW,

          THEN PRESS RESUME TO CONTINUE
```

5. After 30 seconds of high calibration data, the program will automatically pause. Advance tape to start of low calibration data. Press the key "RESUME". Again, the display indicates that data acquisition is in progress.

6. After 30 seconds of low calibration data, the program will automatically pause. When tape has been positioned at start of the data session, computer acquisition is started by pressing the key "RESUME".

7. When the total number of seconds defining this file have elapsed the program screen display will direct the user to: SAVE the file; or DELETE the created digitized file. The screen displays:

SELECT ONE OF THE FOLLOWING [ENTER 1 OR 2]

1 TO SAVE DIGITIZED FILE

2 TO DELETE DIGITIZED FILE

8. If the user has chosen to SAVE the file, it is written to hard disk, and the user may now proceed with data reduction to calculate stroke volume, cardiac output, cardiac index and Heather index. The original menu is displayed:

```
****************************************
*
*  SELECT FROM THE FOLLOWING
*
*  1. DIGITIZE A DATA FILE FROM TAPE
*
*  2. DATA REDUCTION OF DIGITIZED FILE
*
*  3. EXIT
*
****************************************
```

[ENTER 1, 2, OR 3]:

Procedure for data reduction--SELECTION 2

1. The screen will request input from the user as follows:

PHASE 1 -- KEY FIELD ENTRY

****

ENTER RUN ID FOR THIS FILE: (6 digit file name used when digitizing).

ENTER LENGTH (CM) BETWEEN INNER ELECTRODES: (e.g., 26.75)

ENTER HEMATOCRIT COUNT: (e.g., 40)

ENTER HEIGHT (CM): (e.g., 183)

ENTER WEIGHT (KG): (e.g., 94.5)

PHASE 2 -- CALIBRATION VALUES

****

2. The display will show the calibration levels set internal to the program which the user may choose to modify. These default values are:

	High	Low
BASE IMPEDANCE (OHMS)	25.0000	0.0000
dZ/dT (OHMS)	1.0000	0.0000

WOULD YOU LIKE TO CHANGE THESE VALUES (Y/N)

NOTE: If the user enters "N", the screen will display:

****

PHASE 3 -- CALIBRATION ACQUISITION

****

CALIBRATION OF BASELINE IMPEDANCE

****

CHANNEL	SIGNAL	A/DHIGH
1	IMPEDANCE	5400

DO YOU WANT TO RE-RUN HIGH CALS [Y/N]?

NOTE: If the user enters "Y" then the the program will return to the original menu and user must redigitize calibration data from tape. The condition that would require a "Y" response here is obtaining an A/DHIGH value which does not correspond to the voltage out of the Minnesota Cardiograph's internal "Hi CAL" setting. In this example, an A/D value of 5400 equals 0.8 volts. For additional information on determining the ratio of A/D values to voltage, refer to the: Pro/Tool Kit Real-Time Interface Library (PRTIL) User's Guide, Chapter 7, p. 12.

If the user enters "N" then the screen displays

CHANNEL	SIGNAL	A/DLOW
1	IMPEDANCE	433

DO YOU WANT TO RE-RUN LOW CALS [Y/N]?

NOTE: If the user enters "Y" then the the program will return to the original menu and user must redigitize calibration data from tape. If the user enters "N" then the screen displays:

CHANNEL	SIGNAL	ADLOW	ADHI	LOWCAL	HICAL
1	IMPEDANCE	433	5400	0.0000	25.0000

WOULD YOU LIKE TO REPEAT THESE CALIBRATIONS [Y/N]?

NOTE: If the user enters "Y" then the the program will return to the original menu and user must redigitize calibration data from tape. If the user enters "N" then the screen displays

****

CALIBRATION OF dZ/dt SIGNAL

****

CHANNEL	SIGNAL	ADLOW	ADHI	LOWCAL	HICAL
2	dZ/dt	491	1495	0.0000	1.0000

SLOPE 9.960159E-04 INTERCEPT -0.4890438

WOULD YOU LIKE TO REPEAT CALIBRATIONS [Y/N]?

NOTE: If the user enters "Y" then the program will return to the original menu and user must redigitize calibration data from tape. If the user enters "N" and this is the first time these data are to be analyzed, the program will display an informative error message: -FILE DOES NOT EXIST-. It will then create an interim file and proceed directly to DATA REDUCTION AND EDITING. If this is an editing session, the screen will display a list of all 15-second data epochs from which the user has selected at least one waveform for processing. If no waveform was chosen by the user for a particular epoch, that epoch is "ZEROED" (i.e., the epoch number is not listed below and will not be used). A 10-min file where all epochs contain selected data is displayed as follows:

FROM THE RECORD, THE FOLLOWING EPOCHS ARE NONZERO:

1 2 3 4 5 6 7 8 10 11

12 13 14 15 16 17 18 19 20 21

22 23 24 25 26 27 28 29 30 31

32 33 34 35 36 37 38 39 40

PRESS [RETURN] TO CONTINUE

When the [RETURN] key is pressed, the screen will display:

****

DATA REDUCTION AND EDITING

****

ENTER STARTING TIME CODE FOR DATA ON TAPE (e.g., enter 300 for 3:00).

ENTER EPOCH FOR START OF DATA REDUCTION: (e.g., 1)

ENTER LAST DATA EPOCH: (e.g., 40)

The time code entry is recordkeeping information which is not used by the program. It is here for the convenience of the user so that he may keep track of "where" in a particular tape file data reduction was started. If this is an editing session, the user may choose to enter only those epochs needing correction, i.e., new waveforems will be selected. At this point, the screen will display the data of the first 15-sec epoch selected:

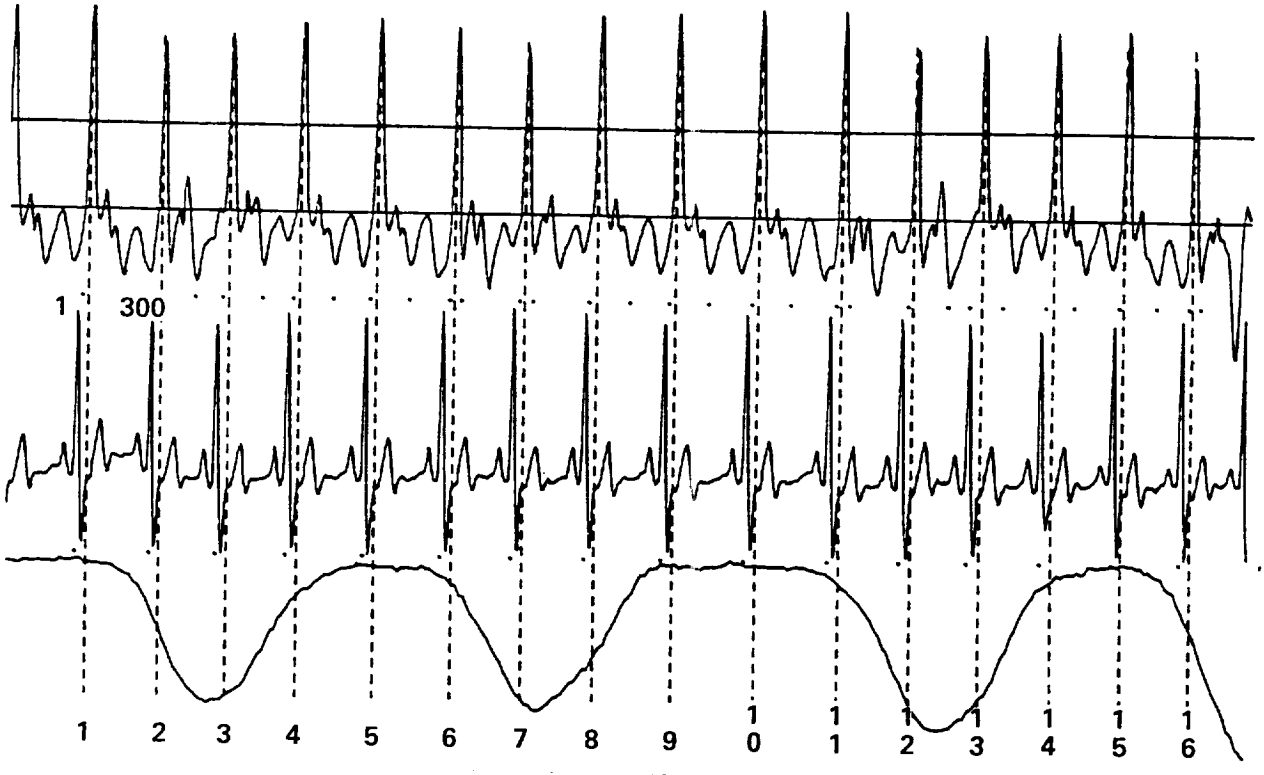

Figure 1.- Example of a screen display showing a 15-sec data epoch.

The first waveform displayed in this figure is the dZ/dt. The horizontal lines through this waveform represent high cal level (upper line) and the low cal level (lower line). The two horizontal dots beneath each dZ/dt waveform mark the point where the rising (major peak) dZ/dt waveform first crosses the low-cal line and the maximum trough (downward spike) following this peak. The distance between these two dots (for a single waveform) is the ventricular ejection time.

The numerics displayed beneath the dZ/dt identify this epoch number and time code at the start of this epoch. In this figure, the display 1 300 means epoch 1, time code 3:00.

The second waveform is the electrocardiogram (ECG) and the horizontal dots beneath the ECG mark the peak of the R-wave. The third waveform shows respiratory cycles (Note that this waveform is inverted, such that the top of each cycle displayed actually represents the expiratory pause between breaths). Vertical dashed lines denote the dZ/dt peaks and their relation to ECG and respiration signals. Each dZ/dt peak (vertical dashed lines) is numbered at the bottom of the screen.

While this display is on the screen, the user is prompted with questions (displayed in upper left corner). The first question is:

SKIP THIS EPOCH? [ENTER Y/N]:

If the user does not want to have this data epoch represented in the stored output file, entering "Y" would cause the program to display the second 15-sec data epoch. No data from the first epoch are stored, and the second epoch is renumbered as epoch 1. If the user enters "N" in response to this question, the next query displayed is

REDO ANALYSIS? [ENTER Y/N]:

One condition that would make the user choose to redo the analysis is that the dZ/dt waveform is significantly distorted by artifact (e.g., electrical noise or movement) and therefore the horizontal dots beneaths the waveform are incorrectly positioned (i.e., ventricular ejection time is incorrectly labeled). Answering "Y" to this question results in the prompt

ENTER GATE AND DIFFERENCE FACTORS SEPARATED WITH A COMMA:

NOTE: The GATE and DIFFERENCE factors are indigenous to the peak detection subroutine used in this program. They are used for determining the peak and delta-t (ventricular ejection time) values of the dZ/dt waveform. Both factors provide a criterion for distinguishing between high frequency noise and significant trends in the waveform. The GATE factor represents the minimum number of consecutive data points (A/D values) needed to establish a trend. The DIFFERENCE factor represents the minimum difference in magnitude between data points that is needed to establish a real increase in the trend. If the current maximum A/D value is greater than the current maximum plus the minimum DIFFERENCE (current minus previous maximum A/D

value), then the counter is incremented. When the counter is equal to the GATE, a trend toward significant peak is established. The default value for GATE is 2 and for DIFFERENCE is 100. If the user feels that the points marking delta-t are "too close together", then a higher DIFFERENCE factor is entered (e.g., 2,200 or 2,300). If the delta-t marks are "too far apart", then a lower DIFFERENCE factor is entered (e.g., 2,50 or 2,75). The GATE factor is rarely modified. After new GATE or DIFFERENCE factors have been entered, the screen blanks, and this epoch is again displayed with the dots marking delta-t repositioned. This process can be repeated until the user is satisfied that most dZ/dt waveforms in this epoch have delta-t correctly marked. If the user enters "N", the next query displayed is

OK TO CALCULATE HEATHER INDEX? [ENTER Y/N]:

If the user enters "N", the output file would contain zeroes for the heather index. The condition that would make the user choose to zero the heather index is when the ECG waveform is so distorted by artifact that the peak of the R-wave cannot be detected (i.e., marked by a dot) by the program. If the user enters "Y", the output file will contain the calculated heather index for those waveform peaks selected below. The next instruction from the program is

LIST SELECTED PEAKS, SEPARATE WITH COMMA: (e.g., 1,5,9,10,14,15)

The criteria for selecting a peak are: (1) no significant artifact should be present in this waveform (and in the waveform immediately preceeding it), (2) delta-t must be correctly marked, and (3) waveforms must occur during the exhalation respiratory plateau (pause between breaths). Refering to figure 1, the user would likely select peaks 1,5,9,10,14, and 15.

After making peak selections, the user presses the "RETURN" key and is prompted with the query

DO YOU WANT A COPY [Y/N]:

Answering "Y" will produce a hard copy of the epoch being displayed on the screen. Answering "N" will prompt the query

DO YOU WANT TO EXIT [Y/N]:

Entering "N" causes the program to display the next 15-sec epoch of data from which the user may select peaks for data reduction. This is repeated until all 15-sec data epochs of this file have been processed. Note that if the user has just completed the last epoch of data in this file, the program terminates automatically (i.e., responds as though a "Y" was entered). Entering "Y" terminates the data reduction phase of the program and the screen will display options for user selection:

ENTER 1 TO SAVE DATA ON FLOPPY AND EXIT

ENTER 2 TO EXIT (SAVE DATA ON HARD DISK)

ENTER 3 TO RESTART DATA EDITNG

ENTER 4 TO RESTART CALIBRATION ACQUISITION

[ENTER 1, 2, 3 OR 4]:

Entering "1" will cause the program to prompt the user for additional key field information used to identify this file. The screen displays

---

GROUP TYPE (maximum of 8 characters): (e.g., CONTROL)

RUN NUMBER: (e.g., 1)

DIRECTION (cc,cw,nd): NOTE: cc=counterclockwise, cw=clockwise

nd=no direction (i.e., no rotation)

SUBJECT'S INITIALS (first and last): (e.g., PC)

AGE: (e.g., 49)

SUSCEPTIBILITY (1,2,3): NOTE: 1 = high motion sickness

susceptible, 2 = moderate and

3 = low.

SEX (m/f): (e.g., M)

TEST DATE (mmmddyy): (e.g., MAY0288)

TEST TIME (military in hr, min, e.g., for 1:00 pm enter 1300):

PRE HEART RATE (in beats/min): (e.g., 68)

PRE TEMPERATURE: (e.g., 97.6)

PRE B.P. (sys,dia, e.g., 120,80):

PRE/POST TEST BASELINE (minutes): (e.g., 10)

PLEASE INSERT DATA FLOPPY WITH AT LEAST 60 CONTIGUOUS FREE BLOCKS INTO DRIVES DZ1 & DZ2. WHEN READY, PRESS RETURN

ARE YOU FINISHED WITH DIGITIZING DATA? [Y/N]

Entering "Y" will prompt the user as follows:

DO YOU WANT TO DELETE THE DIGITIZED FILE? [Y/N]:

(NOTE: After this input, the program returns the user to the original menu).

Entering "2" will return the user to the original menu for this program.

Entering "3" will return the user to the editing portion of this program.

Entering "4" will return the user to the calibration acquisition portion of this program.

REFERENCES

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2. McGregor, M.; Donevan, R.E.; and Anderson, N.M.: Influence of Carbon Dioxide and Hyperventilation on Cardiac Output in Man. J. Appl. Physiol., vol. 17, no. 6, 1962, pp. 933-937.

3. Miller, J.C.; and Horvath, S.M.: Impedance Cardiography, Psychophysiology, vol. 15, no. 5, 1978, pp. 80-91.

APPENDIX

SOURCE CODE

```
C       PROGRAM IMPMLT
C
C       AN IMPEDANCE CARDIOGRAPH PROGRAM USING DIGITIZED DATA FILES
C
        PARAMETER (IFREQ=200)
        DIMENSION SLOPE(2),ENTRCP(2),CALVAL(2,2)
C       COMMON ISPACE(4*IFREQ  ),SPACE(30*IFREQ  )
        REAL*8       DRAW ,IMPACQ ,IMPCAL,IMPSTR

C       ========================================
C       DATA ACQUISITION OF BIOFEEDBACK PARAMETERS
C       ========================================

        REAL TEMPRT,
     @                ZERO,CFREQ,TFREQ,EPOCH

        INTEGER PREDIA,PREHR,PRETEM,PRESYS,PSTDIA,PSTSYS,NUMDIA,
     @          PSTHR,PSTTEM,RUNNUM,IDAY,NSN,AGE,SUSC,
     @          TESTIM,MIN,PSTTST,PART,CHANEL,TOTMIN,PRETST,
     @                 IMINS,IANS,        HIGH( 2,2)       ,DIAG(15),
     @          CLEANS(2),ICLEAN(2)

        LOGICAL*1 SEX,ANS,TEMP,DMY,IRSP,IABORT,IPAWS,TYMEAN,STDDEV,
     @          GROUP(8),DATE(7),DIRECT(2),OSN(2),STRNG(8),
     @          FRMT(12)
        CHARACTER*1 CMT(80),RUN(4),RUNTYP,DATFIL(14),EXP
        CHARACTER*14 CATFIL
        EQUIVALENCE (DATFIL,CATFIL)
C
C
C
C       --------------
C       INITIALIZATION
C       --------------

        DATA IMPCAL/'IMPCAL'/ ,IMPSTR/'IMPSTR'/
        DATA DRAW/'DRAWRM'/ ,ICLEAN/27,99/,IMPACQ/'IMPACQ'/
        DATA CLEANS/27,99      /,CATFIL/'00000000000000'/

        TYPE 500,CLEANS
500     FORMAT(X,4A1)
        TYPE 101
101     FORMAT(10X,60('*'),//,27X,' IMPEDANCE CARDIOGRAPH PROGRAM',
     1 //,10X,60('*'),/////)
125     CONTINUE
        CATFIL(1:14)='00000000000000'
        TYPE 102
```

```
102     FORMAT(20X,45('*'),/,20X,'*',
     1  /,20X,'*',6X,' SELECT FROM THE FOLLOWING',/,20X,'*',
     1  /,20X,'*',10X,'1. DIGITIZE A DATA FILE FROM TAPE',
     2  /,20X,'*',10X,'2. DATA REDUCTION OF DIGITIZED FILE',
     3  /,20X,'*',10X,'3. EXIT',
     4 /,20X,45('*'),/,
     5 /' [ENTER 1, 2 OR 3]: '$)
150     CONTINUE
        ACCEPT  *  ,IANS
        IF(IANS.EQ.1) GOTO 200
        IF(IANS.EQ.2) GOTO 2000
        IF(IANS.EQ.3) GOTO 99999
        TYPE *,' ***** E R R O R - TYPE  1 OR 2 OR 3  ONLY. NOW DO IT'
        GOTO 150
200     CONTINUE
        IEFN=6
C       CALL IMPACQ(CATFIL)
        CALL SPAWN(RAD50(IMPACQ),,,IEFN,,IESD,,,,,,IDS)
D      TYPE *,' SPAWN CALLED ','IEFN= ',IEFN,' IESD= ',IESD,'IDS= ',IDS
        CALL WAITFR(IEFN,IDS2)
C       TYPE *,' IEFN SET NOW ',IDS2
        TYPE 500,CLEANS
        GOTO 125
2000    CONTINUE

C       ===========================
C       PHASE 1 -- KEY FIELD ENTRY
C       ===========================

        TYPE 500,CLEANS
        TYPE 501
501    FORMAT(10X,60('*'),/////,27X,' PHASE 1 -- KEY FIELD ENTRY',/////,
     1 10X,60('*'),/////)

        TYPE 3998
3998    FORMAT (/' ENTER RUN ID FOR THIS FILE:',$)
        ACCEPT 3999,CATFIL(5:10)
3999    FORMAT(A6)
        TYPE 4000
4000    FORMAT(/' LENGTH (CM.) BETWEEN INNER ELECTRODES: ',$)
        ACCEPT  *  ,ELEN
        TYPE 4100
4100    FORMAT(/' HERMATOCRIT COUNT : ',$)
        ACCEPT  *  ,HEM
        TYPE 4200
4200    FORMAT(/' HEIGHT(CM) : ',$)
        ACCEPT  *  ,HEIGHT
        TYPE 4300
4300    FORMAT(/' WEIGHT(KG) : ',$)
        ACCEPT  *  ,WEIGHT

C       ---------------------------------------------
C       SET DEFAULTS AND ZERO CURRENTLY UNUSED FIELDS
C       ---------------------------------------------
```

```
          RHO=53.2*EXP       (.022*HEM)
          BSA=HEIGHT**.725*WEIGHT**.425*.007184
          C=RHO*ELEN**2
D         TYPE *,' C= ',C,'RHO= ',RHO
D         CALL WAIT(5,2)

C         ==============================
C         PHASE 2 -- CALIBRATION VALUES
C         ==============================

6000      CONTINUE
          CALL ERRSET(59,.TRUE.,.FALSE.,.TRUE.,.FALSE.,MAX)
          CALL IMPVAL (CALVAL)

C         ==============================
C         PHASE 3 -- CALIBRATION ACQUISITION
C         ==============================

7010      CONTINUE
          OPEN (UNIT=1,NAME='DW1:NUDRAW.TEL',TYPE='NEW',FORM='FORMATTED')
          WRITE(1,2) CALVAL       ,C,BSA,CATFIL,IMINS
2         FORMAT(6(  G15.7),A14,I10)
          CLOSE (UNIT=1)
          IEFN=6
          CALL SPAWN  (RAD50(IMPCAL),,,IEFN,,IESD,,,,,,IDS)
D         TYPE *,' SPAWN CALLED ','IEFN= ',IEFN,' IESD= ',IESD,'IDS= ',IDS
          CALL WAITFR(IEFN,IDS2)
C         TYPE *,' IEFN SET NOW ',IDS2
          OPEN (UNIT=1,NAME='DW1:NUDRAW.TEL',TYPE='OLD',FORM='FORMATTED')
          READ (1,2) SLOPE,ENTRCP,C,BSA,CATFIL,IMINS
          CLOSE (UNIT=1)

          CATFIL(11:14)='.IMP'
C
C         OPEN INTERNAL FILE THAT STORES RESULTS OF THE REDUCTION PROCESS
C         IF IT EXISTS AND FIND OUT WHAT EPOCHS HAVE BEEN COMPLETED. OTHER
C         WISE CREATE A NEW INTERNAL FILE TO BEGIN REDUCTION
C
          OPEN (UNIT=1,STATUS='OLD',NAME=CATFIL,
       1  FORM='UNFORMATTED',ACCESS='DIRECT',RECL=8,ERR=50)
          CLOSE(UNIT=1)
          CALL INVEST(CATFIL) !DETERMINE WHAT EPOCHS HAVE BEEN COMPLETED
          TYPE *,'PRESS [RETURN] TO CONTINUE '
          ACCEPT 500 ,ANS
          GOTO 55
50        CONTINUE
          OPEN (UNIT=1,STATUS='NEW',NAME=CATFIL,
       1  FORM='UNFORMATTED',ACCESS='DIRECT',RECL=8)
          CLOSE(UNIT=1)
          MAXREC=380
          IF(CATFIL(10:10).EQ.'0') MAXREC=120
          IF(CATFIL(10:10).EQ.'4') MAXREC=220
          CALL ZEREC (MAXREC,CATFIL) !ZERO CONTENTS OF NEW FILE FOR MAX RECS
55        CONTINUE
```

```
C
      IEFN=6
C
C     ============================
C     PHASE 4 -- DATA REDUCTION
C     ============================
C
C     NOTE FOR THIS SPAWNING TO WORK TYPE INSTALL DRAWRM.TSK TO
C     INSTALL THE DRAWED.FTN PROGRAM
C
80000 CONTINUE
      CALL SPAWN(RAD50(DRAW),,,IEFN,,IESD,,,,,,IDS)
D     TYPE *,' SPAWN CALLED ','IEFN= ',IEFN,' IESD= ',IESD,'IDS= ',IDS
      CALL WAITFR(IEFN,IDS2)
C     TYPE *,' IEFN SET NOW ',IDS2
C     ============================
C     PHASE 5 -- DATA STORAGE
C     ============================
C
C


9000  CONTINUE
      TYPE 500,ICLEAN


9101  CONTINUE
      TYPE 9109
9109  FORMAT(//////////)
      TYPE 9110
9110  FORMAT(' WOULD YOU CARE TO ',
     1  /7X,'1) SAVE DATA ON FLOPPY AND EXIT',
     2  /7X,'2) EXIT (SAVE DATA ON DISK)',
     3  /7X,'3) RESTART EDITING',
     4  /7X,'4) RESTART CALIBRATION ACQUISITION (SAVE)',
     5  /' [ENTER 1,2,3,OR 4 ]: ',$)
      ACCEPT 10,TEMP
10    FORMAT(A1)
      IF(TEMP.EQ.'2'.OR .TEMP.EQ.'4') THEN
      OPEN(UNIT=1, NAME='DW1:NUDRAW.TEL',STATUS='OLD')
      CLOSE (UNIT=1,DISPOSE='DELETE')
      END IF
      IF (TEMP.EQ.'1'.OR.TEMP.EQ.'2'.OR.TEMP.EQ.'3'.OR.TEMP.EQ.'4')
     1  GO TO 9114
      TYPE 9108
9108  FORMAT(////' YOU MUST NOT HAVE CHOSEN A VALID ALTERNATIVE;'/,
     @  ' CHOOSE ONE OF THE FOLLOWING: '/)
      GOTO 9101
9114  CONTINUE
      DECODE (1,110,TEMP) ITEMP
110   FORMAT(I1)
      GOTO (9115,99990,80000,6000) ITEMP
```

```
C       ---------------------
C       ASSEMBLE DATAFILE NAME
C       ---------------------

9115    CONTINUE
        CALL SPAWN(RAD50(IMPSTR),,,IEFN,,IESD,,,,,,IDS)
D       TYPE *,' SPAWN CALLED ','IEFN= ',IEFN,' IESD= ',IESD,'IDS= ',IDS
        CALL WAITFR(IEFN,IDS2)
C       TYPE *,' IEFN SET NOW ',IDS2
C       CALL IMPSTR(CATFIL,IFLAG,GROUP,RUNNUM,DIRECT,OSN,AGE,SUSC,SEX,
C     1 DATE,TESTIM,PREHR,TEMPRT,PRETEM,PRESYS,PREDIA,PRETST,PSTTST)
C       TYPE 500,CLEANS
        OPEN(UNIT=1, NAME='DW1:NUDRAW.TEL',STATUS='OLD')
        CLOSE (UNIT=1,DISPOSE='DELETE')
        GOTO 125
C10000   CONTINUE
C       IFLAG=1 ! WRITE COMMENTARY FILE
C       CALL COMENT (KCHAR)
C       GOTO 9101
99990   CONTINUE
        TYPE 500,CLEANS
        GOTO 125
99999   CONTINUE
        END
        SUBROUTINE ZEREC(MAXREC,CATFIL)
        integer tcount
        CHARACTER*14 CATFIL
        OPEN (UNIT=1,STATUS='OLD',NAME=CATFIL,
     1  FORM='UNFORMATTED',ACCESS='DIRECT',RECL=8)

        do 100 tcount = 1,MAXREC
                write(1,REC=TCOUNT,ERR=999)0.,0.,0.,0.,0.,0.,0.,0.
100     continue

999     CLOSE(UNIT=1, STATUS='SAVE')
        RETURN
        END
        SUBROUTINE INVEST(CATFIL)
        DIMENSION BUF(8,1),NONZER(400)
        CHARACTER*14 CATFIL
        CALL ERRSET(36,.TRUE.,.FALSE.,.TRUE. ,.FALSE.)
        IREC=1
        INUM=0
      TYPE *,' FROM THE RECORD, THE FOLLOWING EPOCHS ARE NONZERO :'
100     CONTINUE
        OPEN (UNIT=1, status='old', NAME=CATFIL,ERR=999,
     1       FORM='UNFORMATTED', access='direct',recl=8  )

                read(1,REC=IREC  ,ERR=999)(BUF(ICOUNT,1),ICOUNT=1,8)
        IF( BUF(1,1)) 999,999,200
200     CONTINUE
        INUM=INUM+1
        NONZER(INUM)=IREC
999     CLOSE(UNIT=1, STATUS='SAVE')
```

```
      CALL ERRTST(36,IERR)
      IF(IERR.EQ.1) THEN
      TYPE *,(NONZER(I),I=1,INUM)
      RETURN
      ELSE
      IREC=IREC+1
      GOTO 100
      END IF
      END
      PROGRAM    IMPCAL
C     (SLOPE,INTRCP,CATFIL)
      PARAMETER (IFREQ=200)
      REAL CALVAL(2, 2),INTRCP(2),SLOPE(2)

      INTEGER CLEANS(2),CHANEL,HIGH(2,2)
      COMMON ISPACE(4*IFREQ),SPACE(30*IFREQ)
      EQUIVALENCE(CALVAL,SPACE(1))
      CHARACTER*14 CATFIL
      DATA CLEANS/27,99/
C     ============================
C     PHASE 3 -- CALIBRATION ACQUISITION
C     ============================
      CFREQ=IFREQ
      OPEN(UNIT=1,NAME='DW1:NUDRAW.TEL',TYPE='OLD',ORM='FORMATTED')
      READ (1,2)CALVAL      ,C,BSA,CATFIL,IMINS
2     FORMAT(6(G15.7),A14,I10)
      CLOSE(UNIT=1)
7010  TYPE 500,CLEANS
500   FORMAT(X,4A1)
      TYPE 700
700   FORMAT(10X,60('*'),/////,22X,' PHASE 3 -- CALIBRATION
     1 ACQUISITION',/////,10X,60('*'),/////)
      CATFIL(1:4)='DW1:'
      CATFIL(11:14)='.DIG'
C
C     ------------------------------------
C     CALIBRATE BASELINE IMPEDANCE - CHANNEL 2
C     ------------------------------------
C
      CALL CALZ (SLOPE(1),INTRCP(1),CALVAL,CATFIL)
C
C     ------------------------------------
C     CALIBRATE dZ/dT SIGNAL - CHANNEL 3
C     ------------------------------------
C
      CALL CALDZT (SLOPE(2),INTRCP(2),CALVAL,CATFIL)

      OPEN(UNIT=1,NAME='DW1:NUDRAW.TEL',TYPE='OLD',FORM='FORMATTED')
      WRITE(1,2)SLOPE,INTRCP,C,BSA,CATFIL,IMINS
      CLOSE(UNIT=1)
      END
      SUBROUTINE DIRECT (TCOUNT,CATFIL,NCHAN)
C     STORAGE SEQUENCE AS FOLLOWS:
C     FIRST - RAW RESPIRATION
```

```
C       SECOND - DELTA Z
C       THIRD - DZ/DT
C       FOURTH - ECG

c       TKB FOR TASK BUILD
C
c       TKB>FILENAME=FILENAME
C       TKB>/
C       TKB>MAXBUF=1600
C       TKB>//
c


        PARAMETER (IFREQ=200)
        integer buf(  IFREQ  ), tcount
        DIMENSION X(15*IFREQ),Y(15*IFREQ)
        COMMON BUF,X,Y
        CHARACTER*14 CATFIL

        OPEN (UNIT=1, status='old', NAME=CATFIL          ,
     1       FORM='UNFORMATTED', access='direct',recl=4*IFREQ)

          read(1,REC=TCOUNT,ERR=999)(BUF(ICOUNT  ),ICOUNT=1,4*IFREQ)
100     continue

999     CLOSE(UNIT=1, STATUS='SAVE')
10      FORMAT(x,i3,4(2X,I4,2x,i4))
20      FORMAT(1X,I5)

        RETURN
        END
        SUBROUTINE CALZ (SLOPE,INTRCP,CALVAL,CATFIL)
C       --------------------------
C       CALIBRATE BASELINE IMPEDANCE - CHANNEL 2
C       --------------------------
C
        REAL CALVAL(2, 2),CFREQ,TFREQ,EPOCH,INTRCP
        INTEGER*4 IADSUM
        INTEGER CHANEL,ICOUNT,HIGH( 2),
     @          CLEANS(2),MAXPTS,ISTAT(2),IEFN,MDSYN,
     @          ICHAN(8),ICONV,IFORM,ITRIG,ISTAT2(2),IEFN2,NPTS(2)

        CHARACTER*4,IWORD(2)
        CHARACTER*14,CATFIL

        PARAMETER (IFREQ=200)
        COMMON ISPACE(4*IFREQ),SPACE(30*IFREQ)
        LOGICAL*1         ANS

       DATA IWORD /'HIGH','LOW '/
        DATA CLEANS/27,99/
C
C
C
```

```
C       -------------
C       INITIALIZATION
C       -------------
C       ==============================
C       PERFORM PRELIMINARY ACQUISITION
C       ==============================
        CALL WAIT( 2,2)
        TYPE 500,CLEANS
500     FORMAT(X,4A1)
        TYPE 700
700     FORMAT(10X,60('*'),/////,22X,' CALIBRATION
     ;  OF BASELINE IMPEDANCE',/////,10X,60('*')//////)

        CALL WAIT( 2,2)
        CHANEL=2
C       ---------------------------------
C       ---------------------------------

7001    CONTINUE
C
C      -----------------------------
C      -----------------------------
C
C       OPEN(UNIT=2,NAME='SY:DUMP.TST',FORM='FORMATTED',TYPE='NEW')
        ISTREC=1
7019    CONTINUE
        N=1  !HIGH CALIBRATIONS
C       ----------------------
C       PERFORM HIGH CALIBRATION
C       ----------------------
C       CALIB=.TRUE.

7110    CONTINUE

C       --------------------
C       INITIALIZE SLOPE,INTERCEPT
C       --------------------

           SLOPE = 0.0
           INTRCP = 0.0
           NSAMP=0
           IADSUM=0

        DO 7000 I=0,29
        IREC= 30*(N-1)+ISTREC+I
        CALL DIRECT(IREC,CATFIL)
C
C
C

C        -------------------------------
C        CALCULATE MEAN
C        -------------------------------
C
```

```
          NPTCHN=IFREQ !NUMBER OF SAMPLES PER CHANNEL PER RECORD=PER SECOND
          DO 704 J=1,NPTCHN
          IADSUM=IADSUM+ISPACE  ( (J-1)*4+CHANEL  )
C         TYPE *,IADSUM,ISPACE  ( (J-1)*4+CHANEL  )
         NSAMP=NSAMP+1
C      WRITE(2,19999)IAD(I+(J-1)*CHANEL+(K-1)*MAXPTS),NPTCHN,CHANEL,
C     1  NPTS(K),NSAMP,I,J,K,N
C19999   FORMAT(9I8)
704       CONTINUE
C         WRITE(2,*) IADSUM,NSAMP,ISPACE
7000      CONTINUE
          HIGH(N)=IADSUM/NSAMP
C
C         ------------------------------------
C         ECHO MEAN AND VERIFY
C         ------------------------------------
C

          TYPE 715,IWORD(N)
715    FORMAT(/////////'  CHANNEL  ',5X'   SIGNAL  ',5X,'A/D',A4,
     1       /,' ----------',5X,'----------',5X,'----------')

        TYPE 71550 , HIGH(N)
71550    FORMAT(   5X,' 1',8X,'IMPEDANCE ',5X,I10)
         TYPE 717,IWORD(N)
717      FORMAT(/' DO YOU WANT TO RE-RUN ',A4,' CALS [Y/N]? ',$)
         ACCEPT 617,ANS
617      FORMAT(A1)
         IF (ANS .EQ. 'Y'.OR.ANS.EQ.'y') THEN
         TYPE *,' WHAT STARTING RECORD '
         ACCEPT *,ISTREC
         GOTO 7110
         END IF
         IF (N.EQ.2) GOTO 724
         N=2
         GOTO 7110

724      CONTINUE

C        ----------------------------
C        CALCULATE SLOPE AND INTERCEPT
C        ----------------------------

            IF (HIGH(1) .NE. HIGH(2)) GOTO 7185
            INTRCP = 0.0
            SLOPE = 0.0
            GOTO 718
7185   SLOPE = (CALVAL(2,1)-CALVAL(1,1))/FLOAT (HIGH(1)-HIGH(2))
            INTRCP = CALVAL(1,1) - SLOPE*FLOAT(HIGH(2))
718      CONTINUE

C        --------------------
C        ECHO SLOPE,INTERCEPT
C        --------------------
```

```
      TYPE 720
720   FORMAT(/' CHANNEL  ',5X,' SIGNAL  ',5X,' ADLOW   ',5X,
     1' ADHI    ',5X,
     2 '  LOWCAL ',5X,'  HICAL  ',/,X,6('---------',5X))
        TYPE 81550 , HIGH(2)
81550   FORMAT(   4X,' 1',7X,'IMPEDANCE ',4X,I10,$)
          TYPE 722,HIGH (1),CALVAL(1,1),CALVAL (2,1)
721     CONTINUE
722     FORMAT('+',4X,I10,4X,F10.4,4X,F10.4)
        TYPE 723
723     FORMAT(/' WOULD YOU LIKE TO REPEAT CALIBRATIONS [Y/N]?',$)
        ACCEPT 617,ANS
        IF (ANS .EQ. 'Y'.OR.ANS.EQ.'y') THEN
        TYPE *,' WHAT STARING RECORD '
        ACCEPT *,ISTREC
        GOTO 7019
        END IF
        CLOSE (UNIT=2)
        RETURN
        END
        FUNCTION  MAXIAD (IAD,MAXPTS,NPTS)
        DIMENSION  IAD(NPTS*MAXPTS)
        MAXIAD= IAD(3)
        DO 100 J=1,MAXPTS
        IF(IAD((J-1)*NPTS+3   ).LT.MAXIAD) GOTO 100
        MAXIAD= IAD((J-1)*NPTS+3)
100     CONTINUE
        RETURN
        END
        FUNCTION  MINIAD (IAD,MAXPTS,NPTS)
        DIMENSION  IAD(NPTS*MAXPTS)
        MINIAD= IAD(3)

        DO 100 J=1,MAXPTS
        IF(IAD((J-1)*NPTS+3 ).GT.MINIAD) GOTO 100
        MINIAD=IAD((J-1)*NPTS+3)
100     CONTINUE
        RETURN
        END
        SUBROUTINE CALDZT (SLOPE,INTRCP,CALVAL,CATFIL)
C       ---------------------------
C       CALIBRATE dZ/dT SIGNAL - CHANNEL 3
C       ---------------------------
C
        REAL CALVAL(2, 2),CFREQ,TFREQ,EPOCH,INTRCP
        INTEGER*4 IADSUM,IAD4,IAD4MX,IADELT
        INTEGER CHANEL,ICOUNT,HIGH(2),IAD(400),
     @          CLEANS(2),MAXPTS,ISTAT(2),IEFN,MDSYN,
     @          ICHAN(8),ICONV,IFORM,ITRIG,ISTAT2(2),IEFN2,NPTS(2)

        PARAMETER (IFREQ=200)
        COMMON ISPACE(4*IFREQ),SPACE(30*IFREQ)
        EQUIVALENCE (IAD,ISPACE)
```

```
      CHARACTER*4,IWORD(2)
      CHARACTER*14,CATFIL

C
C
C
C     --------------
C     INITIALIZATION
C     --------------

      DATA CLEANS/27,99/
C     ==============================
C     PERFORM PRELIMINARY ACQUISITION
C     ==============================
      TYPE 500,CLEANS
500   FORMAT(X,2A1)
      TYPE 700
700   FORMAT(10X,60('*'),/////,22X,'  CALIBRATION
     1 OF dZ/dT SIGNAL',/////,10X,60('*'),/////)
      CALL WAIT(5,2)

      CHANEL=3
C     ---------------------------------
C     ---------------------------------

7001  CONTINUE
C
C     ----------------------------
C     ----------------------------
C
7015  CONTINUE
C
C     ------------------------------------------------------------
C     ------------------------------------------------------------
C
7019  CONTINUE
C     OPEN(UNIT=2,NAME='SY:DUMP.TST',FORM='FORMATTED',TYPE='NEW')

      N=1 !HIGH CALIBRATIONS
      SLOPE=0.0
      INTRCP=0.0
713   CONTINUE
      NCHAN=0
      NSAMP=0
      IADSUM=0

C     ------------------
C     READ IN A-D VALUES
C     ------------------

      IREC= 31+I
C     TYPE *,' IREC= ',IREC,'N= ',N,'I= ',I
      CALL DIRECT(IREC,CATFIL)
D     TYPE *,(IAD((J-1)* 4  +3),J=1,100)
```

```
 71400   CONTINUE
 71300   CONTINUE
C
C
C

C        --------------------------------
C        CALCULATE MEAN
C        --------------------------------
C
         IF(N.EQ.1) THEN
C        FIND MAX VALUE IF N=1
         IADMAX=MAXIAD(IAD,IFREQ ,4    )
D        TYPE *,' IADMAX= ',IADMAX
         IADELT=IADMAX
         IADELT=IADELT*5
         IF(IADELT.LT.0) IADELT=-IADELT
         ELSE
C        FOR N=2 FIND MAX AND MIN
C        IADMAX=NUL(IAD,MAXPTS,NPTS)
         IADMAX=MAXIAD(IAD,IFREQ,4       )
         IADMIN=MINIAD(IAD,IFREQ,4       )
         IZERO=IADMIN+(IADMAX-IADMIN)*2/5
         END IF
          NPTCHN=IFREQ
          DO 704 J=1,NPTCHN
         IF(N.EQ.1) THEN
C
C        USE IAD VALUE IF IAD     >= MAX VALUE- 5%*(MAX VALUE)
C
         IAD4=IAD((J-1)*4+CHANEL )
         IAD4MX=IADMAX
         IF((100*IAD4).GE.(IAD4MX*100-IADELT    )) THEN
         NCHAN=NCHAN+1
          IADSUM=IADSUM+IAD ((J-1)*4+CHANEL    )
C        TYPE *,IAD4,IADELT,IAD4MX
         END IF
         ELSE
         IF(IAD((J-1)*4+CHANEL ).LE.IZERO +80.AND.
     1   IAD((J-1)*4+CHANEL ).GE.IZERO -80) THEN
         NCHAN=NCHAN+1
          IADSUM=IADSUM+IAD ((J -1)*4+CHANEL  )
         END IF
         END IF
C      WRITE(2,19999)IAD(J+(K-1)*MAXPTS),NPTCHN,CHANEL,
C     1  NPTS(K),NCHAN,I,J,K,IADMAX
19999    FORMAT(9I8)
704       CONTINUE
7000     CONTINUE
          HIGH(N)=IADSUM/NCHAN
         IF (N.EQ.2) GOTO 714
         N=2
         GOTO 713
714       CONTINUE
```

```
C       ----------------------------------
C       ECHO MEANS AND VERIFY
C       ----------------------------------
C

C       WRITE(2,*    ) IAD,HIGH,IADMAX,IADMIN,IZERO
C        TYPE 715,IWORD(N)
715   FORMAT(/////////'  CHANNEL  ',5X'   SIGNAL  ',5X,'A/D',A4,
     1      /,' ----------',5X,'----------',5X,'----------')
C          TYPE 71551 , HIGH(N)

71551   FORMAT(   5X,' 2',8X,'    dZ/dT ',5X,I10)

C       TYPE 717
717     FORMAT(/' DO YOU WANT TO RE-RUN dZ/dT CALS [Y/N]? ',$)
C       ACCEPT 617,ANS
617     FORMAT(A1)
C       IF (ANS .EQ. 'Y'.OR.ANS.EQ.'y') GOTO 7110

        CLOSE(UNIT=2)

C       ------------------------------
C       CALCULATE SLOPE AND INTERCEPT
C       ------------------------------

           IF (HIGH(1) .NE. HIGH(2)) GOTO 7185
           INTRCP = 0.0
           SLOPE = 0.0
           GOTO 718
7185  SLOPE = (CALVAL(2,2)-CALVAL(1,2))/FLOAT (HIGH(1)-HIGH(2))
           INTRCP = CALVAL(1,2) - SLOPE*FLOAT(HIGH(2))
718     CONTINUE

C       --------------------
C       ECHO SLOPE,INTERCEPT
C       --------------------

        TYPE 720
720   FORMAT(/' CHANNEL  ',5X,' SIGNAL  ',5X,' ADLOW   ',5X,
     1' ADHI    ',5X,
     2 '  LOWCAL ',5X,'  HICAL  ',/,X,6('----------',5X))
            TYPE 81551 , HIGH(2)
81551   FORMAT(   4X,' 2',7X,'    dZ/dT ',4X,I10,$)
           TYPE 722,HIGH (1),CALVAL(1,2),CALVAL (2,2)
722     FORMAT('+',4X,I10,4X,F10.4,4X,F10.4)
        TYPE *, ' SLOPE ',SLOPE,' INTERCEPT ', INTRCP
        TYPE 723
723     FORMAT(/' WOULD YOU LIKE TO REPEAT CALIBRATIONS [Y/N]?',$)
        ACCEPT 617,ANS
        IF (ANS .EQ. 'Y'.OR.ANS.EQ.'y') THEN
        TYPE *,' WHAT STARING RECORD '
        ACCEPT *,ISTREC
        GOTO 7019
        END IF
```

```
      RETURN
      END
C     PROGRAM IMPACQ
      REAL TEMPRT,CALVAL(2, 2),MEAN(2 ),SD( 2),SLOPE( 2),INTRCP( 2),
     @          ADSUM,VARIAN( 2),ZERO,CFREQ,TFREQ,DEV( 2),EPOCH

      INTEGER IOSB(2),BLINK(3),RESET(2),
     @         ISTA(4),ICONT(2),
     @         MIN,CHANEL,ICLK,IADCSR,
     @         ICOUNT,IMINS,IANS,LOW(10),HIGH(10)          ,DIAG(15),
     @         CLEANS(2),MAXRUN,MAXPTS,ISTAT(2),IEFN(2),MDSYN,
     @        ICHAN(8),ICONV,IFORM,ITRIG,ISTAT2(2),IEFN2,NPTS(2)
      INTEGER IEFN1,IPAR(6),ISTAT3(2)

      LOGICAL*1 EXP,SEX,ANS,TEMP,DMY,                    TYMEAN,STDDEV,
     @         DATFIL(14),STRNG(8),
     @         FRMT(12)
      CHARACTER*14 CATFIL
      CHARACTER*1  IBUF,IPAWS,IABORT,IRSP
               PARAMETER (IFREQ =200 ) ! SETS PROGRAM SIZE WRT SAMPLE RATE
               PARAMETER (MDSYN=1)
               PARAMETER (MODE =0)
               PARAMETER (ICONV=0)
               PARAMETER (IFORM=0)
               PARAMETER (ITRIG=0)
               PARAMETER (ITIME=0)
               PARAMETER (CHANEL=4)
      INTEGER*4 IADSUM ,AD( 8),ISIZE
      INTEGER*2 IAD(8*IFREQ ),IAD2(4*IFREQ),IAD1(4*IFREQ)
      EQUIVALENCE (IAD1,IAD),(IAD2,IAD(4*IFREQ+1)),(ISTAT,ISTA),
     1 (ISTAT2,ISTA(3)),(IEFN(1),IEFN1),(IEFN(2), IEFN2)
      COMMON IAD
C
C
C
C     --------------
C     INITIALIZATION
C     --------------

      DATA CLEANS/27,99/
      DATA BLINK/155,53,109/,RESET/155,109/
      DATA FRMT/'(',' ',' ','(','X',',','F','9','.','4',')',')'/
      DATA ICLK/"172540/
      DATA IREAD/"001000/
      DATA IABORT/ "101  /, IPAWS/"120/
500   FORMAT(X,4A1)
510   FORMAT(X,5A1)
617   FORMAT(A1)
618   FORMAT(A6)
7125  FORMAT(/' AIN STATUS WAS:')
7017  FORMAT(' STAT(1) (OCTAL) =',O6,' ISTAT(2) (DECIMAL) = ',I6)
7135  FORMAT (' TRY AGAIN.')
10    FORMAT(I2)
```

```
C       ==========================
C       PHASE 5 -- DATA ACQUISITION
C       ==========================
        FREQ=IFREQ
        MAXPTS=4*IFREQ
        CALL GETADR(IPAR(1),IBUF)
        IPAR(2)=1
9000    TYPE 500,CLEANS
        TYPE 900
900     FORMAT(10X,60('*'),/////,22X,' DIGITIZING A DATA FILE ',
     1  /////,10X,60('*'),////)

C       ---------------------------
C       REQUEST MAXIMUM RUN DURATION
C       ---------------------------

        TYPE 90109
90109   FORMAT(///' PLEASE ENTER RUN ID FOR THIS DATA FILE: ',$)
        ACCEPT 618,(CATFIL(5:10))
        CATFIL(1:4)='DW1:'
        CATFIL(11:14)='.DIG'
        TYPE 90110
90110   FORMAT(///' PLEASE ENTER RUN TIME (IN SECS.)FOR TAPE FILE: ',$)
        ACCEPT *,MAXRUN
        ISIZE=6.25 *MAXRUN+1
        TYPE 90111
90111   FORMAT(///' HOW FAST TO SAMPLE THE DATA ON TAPE ? ',
     1  /10X,' ENTER 1 FOR REAL TIME RATE ',
     2  /10X,' ENTER 2 FOR TWICE REAL TIME ',
     3  /' [ENTER 1 OR 2] NOW: ',$)
        ACCEPT *,ISAMP

C       NOTE: MAXPTS=FREQ*4
        CFREQ=FREQ*ISAMP
        CALL SETFRQ(CFREQ,TFREQ)
        DO 190 I=1,4
        ICHAN(I)=1
190     CONTINUE
        IEFN1=8
        IEFN2=10
        ICOUNT=2*MAXPTS
C       ------------------------
C       OPEN TEMPORARY DATA FILE
C       ------------------------

9015    CONTINUE
C       OPEN(UNIT=2,NAME='SY:TEMP.DAT',TYPE='NEW')
        OPEN (UNIT=1,STATUS='NEW',NAME=CATFIL,INITIALSIZE=-ISIZE,
     1  FORM='UNFORMATTED',ACCESS='DIRECT',RECL=4*IFREQ)

        MIN = 0
        IMINS = 0
```

```
C       --------------------
C       INITIALIZE SUM,ICOUNT
C       --------------------

9011    CONTINUE
        ICONT(1)=ICOUNT/2
        ICONT(2)=ICOUNT/2
        CALL AINIT (ISTAT,IEFN1)
        IF(ISTAT(1).EQ."40000.OR.ISTAT(1).EQ."40040) GOTO 7000
        TYPE *,' ISTAT(1) = ',ISTAT(1)
        PAUSE
7000    CONTINUE

        TYPE *,' '
        IF (IRSP .NE. IPAWS)GO TO 9022
        PAUSE
        TYPE 500,BLINK
        TYPE 7100
7100    FORMAT(/' ******************************',
     1          /' *   DATA COLLECTION RESUMED  *',
     2          /' ******************************')
        TYPE 500,RESET
        GO TO 901
9022    TYPE 9012
9012    FORMAT (' HIT "S" TO START, "P" TO PAUSE,',
     @  ' "A" TO ABORT:'/' FOLLOWED BY A [RETURN]')
        ACCEPT 617, ANS
        IF (ANS .EQ. 'A') GO TO 9100
        IF (ANS .EQ. 'P') PAUSE
        TYPE 500,CLEANS
        TYPE 500,BLINK
        TYPE 97100
97100   FORMAT(///////////////,
     1          /' ******************************',
     2          /' *  DATA COLLECTION UNDERWAY  *',
     3          /' ******************************')

        TYPE 500,RESET
901     CONTINUE
        CALL QIO(IREAD,7, 4,,IOSB,IPAR,IDSW)
        CALL AIN  (ISTAT,               ! START CLOCK
     2  IAD  ,
     3  ICONT(1),
     4  IEFN1,
     5  MDSYN,
     6  ICHAN,
     7  ICONV,
     8  IFORM,
     9  ITRIG,ITIME,CFREQ)
        CALL ABUF(ISTAT2,IAD2,ICONT(2),IEFN2,MDDE ,ITIME)
908     CONTINUE
        IMINS = IMINS + 1
C       TYPE *,' IMINS= ',IMINS
        K=1
```

```
C       N=1
C       IEND=ICOUNT
80001   CONTINUE
        IISTAT=ISTA(1+2*(K-1))
        IF (IISTAT          .EQ."40000.OR.IISTAT          .EQ."40040)
     1  GOTO 81300
C       IF (IISTAT.NE.0) TYPE *,K,IISTAT
        TYPE *,K,IISTAT,IMINS
        GOTO 80001
81300   CONTINUE
C
C
C       ------------------------------------------------
C       STORE DIGITIZED DATA FOR EACH SECOND
C       ------------------------------------------------
C
        CALL DIRECT(IMINS,K)
        NCONT=ICONT(K)
      CALL ABUF(ISTA(1+2*(K-1)),IAD(1+(K-1)*MAXPTS),NCONT     ,IEFN(K),
     1 MODE,ITIME)

C       ---------------------------------
C       ECHO MEANS AND STANDARD DEVIATIONS
C       ---------------------------------

C       ---------------------------------------
C       IF END OF SESSION, END DATA ACQUISITION
C       ---------------------------------------
        MIN = IMINS
        IF(MIN.EQ. 30) THEN
        CALL ACSTAT(ISTAT,JSTAT,1,IEFN1,0)
        CALL QIO("12,9)
        CALL QIO("12,7)
        PAUSE ' - ADVANCE TAPE TO START OF LOW CALS NOW; THEN '
        CALL AINIT(ISTAT,IEFN1,0)
        TYPE 500,BLINK
        TYPE 7100
        TYPE 500,RESET
        GOTO 901
        END IF
        IF(MIN.EQ. 60) THEN
        CALL ACSTAT(ISTAT,JSTAT,1,IEFN1,0)
        CALL QIO("12,9)
        CALL QIO("12,7)
        PAUSE ' - ADVANCE TAPE TO START OF DATA NOW; THEN '
        CALL AINIT(ISTAT,IEFN1,0)
        TYPE 500,BLINK
        TYPE 7100
        TYPE 500,RESET
        GOTO 901
        END IF
        IF (MIN .GE. MAXRUN) GO TO 9100
```

```
C       ---------------------------------------
C       IF PAUSE OR ABORT, END DATA ACQUISITION
C       ---------------------------------------
        CALL READEF( 4,IEF)
        IF(IEF      .GT.0) THEN
        IRSP =IBUF
        IF (IRSP .EQ. IPAWS) THEN
                CALL ACSTAT(ISTAT,JSTAT,1,IEFN1,0)
        CALL QIO("12,9)
C       CALL QIO("12,7)
        CALL AINIT (ISTAT,IEFN1,0)
        GOTO 7000
        ELSE
        IF (IRSP .EQ. IABORT) GO TO 9100
        END IF
C       SOMETHING ELSE TYPED IN; QUE I/O REQUEST AGAIN
        CALL QIO(IREAD,7, 4,,IOSB,IPAR,IDSW)
        END IF
        IK=K
        IF(IK.EQ.1) K=2
        IF(IK.EQ.2) K=1
        IMINS=IMINS+1
        GOTO 80001

C       ============================================
C       CLEAN UP AND EXIT
C       ============================================

9100    CONTINUE
        TYPE 500,RESET
        CLOSE(UNIT=2)
        CALL QIO("12,7)
        TYPE 91000
91000   FORMAT (//////,10X,'SELECT ONE OF THE FOLLOWING [ENTER 1 OR 2]',
     1  /20X,'1 TO SAVE DIGITIZED FILE ',
     2  /20X,'2 TO DELETE DIGITIZED FILE ',$)
        ACCEPT 617,ANS
        IF(ANS.EQ.'1') THEN
        CLOSE(UNIT=1)
        ELSE IF(ANS.EQ.'2') THEN
        CLOSE(UNIT=1, STATUS='DELETE')
        ELSE
        GO TO 9100
        END IF
        CALL ACSTAT(ISTAT3,JSTAT,1, 5   ,0)
        CALL QIO("12,7)
        CALL QIO("12,9)
        END
        SUBROUTINE DIRECT (TCOUNT,K)
C       STORAGE SEQUENCE AS FOLLOWS:
C       FIRST - RAW RESPIRATION
C       SECOND - DELTA Z
C       THIRD - DZ/DT
C       FOURTH - ECG
```

```
c       TKB FOR TASK BUILD
C
c       TKB>FILENAME=FILENAME
C       TKB>/
c

        PARAMETER (IFREQ=200)
        integer buf(8*IFREQ), tcount
        COMMON BUF

C       do 100 tcount = 1,2
      WRITE(1,REC=TCOUNT,ERR=999)(BUF((K-1)*4*IFREQ+ICOUNT),
     1ICOUNT=1,4*IFREQ)
C               TYPE *,'OK ON READ'
C               do 200 i = 1, 200
C                       write(5,10)i,(BUF(ICOUNT,1),ICOUNT=(i-1)*4+1,i*4)
C200            continue
C               TYPE *,'OK ON WRITE'
100     continue

10      FORMAT(x,i3,4(2x,i4))
20      FORMAT(1X,I5)

999     CONTINUE
        RETURN
        END
        SUBROUTINE SETFRQ(CFREQ,TFREQ)
C
C*******************************************************************************
C
C     SUBROUTINE GETFRQ(CFREQ,TFREQ)
C
C     LANGUAGE: FORTRAN-77
C
C
C     FUNCTION:
C       This SUBROUTINE will prompt the user for the desired clock frequency to
C       be used in acquiring analog data.
C
C
C     OUTPUTS:
C       CFREQ = REAL*4 variable containing the user's desired frequency in hz.
C       TFREQ = REAL*4 variable containing the user's actual frequency in hz.
C
C
C     SUBROUTINES REFERENCED:
C                     SUBROUTINE CLKFRQ.
C
C
C       ***************************************************************
C
C       ***************************************************************
C
C
```

```
      REAL*4 CFREQ,TFREQ                !Declare desired, actual frequencies.
C
1     CONTINUE
      CALL CLKFRQ(CFREQ,TFREQ)
      IF(TFREQ.NE.-999.0) GO TO 2       !Skip ahead if CFREQ is ok.
C
      TYPE 9015
9015  FORMAT(/,1X,'Bad frequency, please try again',/)
      GO TO 1                           !Prompt for frequency again.
C
2     CONTINUE
999   RETURN                            !Return to caller.
      END
      PROGRAM    IMPSTR
C
C     AN IMPEDANCE CARDIOGRAPH PROGRAM USING DIGITIZED DATA FILES
C
      PARAMETER (IFREQ=200)
      DIMENSION SLOPE(2),ENTRCP(2)
C     COMMON ISPACE(4*IFREQ  ),SPACE(30*IFREQ  )
      REAL*8       DRAW ,IMPACQ ,IMPCAL

C     ========================================
C     DATA ACQUISITION OF BIOFEEDBACK PARAMETERS
C     ========================================

      REAL TEMPRT,
     @               ZERO,CFREQ,TFREQ,EPOCH

      INTEGER PREDIA,PREHR,PRETEM,PRESYS,PSTDIA,PSTSYS,NUMDIA,
     @        PSTHR,PSTTEM,RUNNUM,IDAY,NSN,AGE,SUSC,
     @        TESTIM,MIN,PSTTST,PART,CHANEL,TOTMIN,PRETST,
     @              IMINS,IANS,        HIGH( 2,2)       ,DIAG(15),
     @        CLEANS(4),ICLEAN(2)

      LOGICAL*1 SEX,ANS,TEMP,DMY,IRSP,IABORT,IPAWS,TYMEAN,STDDEV,
     @        GROUP(8),DATE(7),DIRECT(2),OSN(2),STRNG(8),
     @        FRMT(12)
      CHARACTER*1 CMT(80),RUN(4),RUNTYP,DATFIL(14),EXP
      CHARACTER*14 CATFIL
      EQUIVALENCE (DATFIL,CATFIL)
      DATA CLEANS/27,91,50,74/
C     OPEN (UNIT=1,NAME='NUDRAW.TEL',FORM='FORMATTED',TYPE='OLD')
C     READ(1,2) SLOPE,ENTRCP,C,BSA,CATFIL,MAXREC
C2     FORMAT (6(G15.7),A14,I10)
C     CLOSE(UNIT=1)
9115  CONTINUE
C     TYPE 5020
5020  FORMAT(/' EXPERIMENT DESIGNATION (A,B,...): ',$)
C     ACCEPT 5021,EXP
5021  FORMAT (A1)
      TYPE 5030
5030  FORMAT(/' GROUP TYPE (maximum of 8 characters): ',$)
      ACCEPT 5031,(GROUP(I),I=1,8)
```

```
5031    FORMAT(8A1)
C       TYPE 5040
5040    FORMAT(/' RUN TYPE (maximum of 4 characters): ',$)
C       ACCEPT 5041,(RUN(I),I=1,4)
5041    FORMAT (4A1)
        TYPE 5050
5050    FORMAT(/' RUN NUMBER: ',$)
        ACCEPT *,RUNNUM
        TYPE 5060
5060    FORMAT(/' DIRECTION (cc,cw,nd): ',$)
        ACCEPT 5061,(DIRECT(I),I=1,2)
5061    FORMAT (2A1)
C       TYPE 5070
5070    FORMAT(/' DAY NUMBER: ',$)
C       ACCEPT *,IDAY
C       TYPE 5080
5080    FORMAT(/' NEW SUBJECT NUMBER: ',$)
C       ACCEPT *,NSN
        TYPE 5090
5090    FORMAT(/' SUBJECT''S INITIALS (first and last): ',$)
        ACCEPT 5091,(OSN(I),I=1,2)
5091    FORMAT (2A1)
        TYPE 5100
5100    FORMAT(/' AGE: ',$)
        ACCEPT *,AGE
        TYPE 5110
5110    FORMAT(/' SUSCEPTIBILITY (1,2,3): ',$)
        ACCEPT *,SUSC
        TYPE 5120
5120    FORMAT(/' SEX (m/f): ',$)
        ACCEPT 5121,SEX
5121    FORMAT (A1)
        TYPE 5130
5130    FORMAT(/' TEST DATE (mmmddyy): ',$)
        ACCEPT 5131,(DATE(I),I=1,7)
5131    FORMAT (7A1)
        TYPE 5140
5140  FORMAT(/' TEST TIME (military in hrs and mins, e.g. for 1:30 p.m.'
     @          ,' enter 1330): ',$)
        ACCEPT *,TESTIM
        TYPE 5150
5150    FORMAT(/' PRE HEART RATE (in beats/min): ',$)
        ACCEPT *,PREHR
        TYPE 5160
5160    FORMAT(/' PRE TEMPERATURE: ',$)
        ACCEPT *,TEMPRT
        PRETEM = IIFIX(TEMPRT*10.0)
        TYPE 5170
5170    FORMAT(/' PRE B.P. (sys,dias  ,e.g. 120,80): ',$)
        ACCEPT *,PRESYS,PREDIAS
        TYPE 5180
5180    FORMAT(/' PRE/POST TEST BASELINE (in minutes): ',$)
        ACCEPT *,PRETST
        PSTTST = PRETST
```

```
      CATFIL(11:14)='.IMP'
      CALL STORE (CATFIL,IFLAG,GROUP,RUNNUM,DIRECT,OSN,AGE,SUSC,SEX,
     1 DATE,TESTIM,PREHR,TEMPRT,PRETEM,PRESYS,PREDIA,PRETST,PSTTST)
      TYPE 500,CLEANS
500   FORMAT(X,4A1)
      END
      SUBROUTINE STORE (CATFIL,IFLAG,GROUP,RUNNUM,DIRECT,OSN,AGE,
     1 SUSC,SEX,DATE,TESTIM,PREHR,TEMPRT,PRETEM,PRESYS,PREDIA,PRETST,
     2 PSTTST)
C
C     AN IMPEDANCE CARDIOGRAPH PROGRAM USING DIGITIZED DATA FILES
C
      DIMENSION SLOPE(2),ENTRCP(2)
      COMMON DATCAR(4,2)
      REAL*8       DRAW

C     ========================================
C     DATA ACQUISITION OF BIOFEEDBACK PARAMETERS
C     ========================================

      REAL TEMPRT,MEAN(4),SD(4),
     @              ZERO,CFREQ,TFREQ,EPOCH

      INTEGER PREDIA,PREHR,PRETEM,PRESYS,PSTDIA,PSTSYS,NUMDIA,
     @        PSTHR,PSTTEM,RUNNUM,IDAY,NSN,AGE,SUSC,
     @        TESTIM,MIN,PSTTST,PART,CHANEL,TOTMIN,PRETST,
     @              IMINS,IANS,       HIGH( 2,2)       ,DIAG(15),
     @        CLEANS(4),ICLEAN(2)

      LOGICAL*1 SEX,ANS,TEMP,DMY,IRSP,IABORT,IPAWS,TYMEAN,STDDEV,
     @        GROUP(8),DATE(7),DIRECT(2),OSN(2),STRNG(8),
     @        FRMT(12)
      CHARACTER*1 CMT(80),RUNTYP,DATFIL(14),EXP
      CHARACTER*4 RUN
      CHARACTER*14 CATFIL,IMPFIL
      EQUIVALENCE (DATCAR,MEAN),(DATCAR(1,2),SD)

      DATA DRAW/'DRAWRM'/ ,ICLEAN/27,99/
      DATA CLEANS/27,91,50,74/

C     IFLAG=0
C     TYPE 500,CLEANS
500   FORMAT(X,4A1)

     OPEN (UNIT=1,STATUS='OLD',NAME='DW1:NUDRAW.TEL',FORM='FORMATTED')
      READ(1,2) SLOPE,ENTRCP,C,BSA,IMPFIL,MAXREC
2     FORMAT(6(  G15.7),A14,I10)
      CLOSE(UNIT=1,DISPOSE='SAVE')
      IMPFIL(12:14)='IMP'
      MIN=MAXREC/4 ! THERE ARE 4 EPOCHS PER MINUTE
      N=1 !SET FOR FIRST DISKETTE
```

```
C       ---------------------
C       ASSEMBLE DATAFILE NAME
C       ---------------------

9115    CONTINUE
        CALL ERRSET(63,.TRUE.,.FALSE.,.FALSE.,.FALSE.,MAX)
        CALL ERRSET(36,.TRUE.,.FALSE.,.TRUE.,.FALSE.,MAX)
        CALL ERRSET(29,.TRUE.,.FALSE.,.TRUE.,.FALSE.,MAX)
        EXP=IMPFIL(5:5)
        DECODE(2,9112,IMPFIL(6:7)) NSN
        DECODE(2,9112,IMPFIL(8:9)) IDAY
        IF (IMPFIL(10:10)     .EQ. '0') RUN(1:4)='BSLN'
        IF (IMPFIL(10:10)     .EQ. '1') RUN(1:4)='CSSI'
        IF (IMPFIL(10:10)     .EQ. '2') RUN(1:4)='TRAN'
        IF (IMPFIL(10:10)     .EQ. '3') RUN(1:4)='    '
        IF (IMPFIL(10:10)     .EQ. '4') RUN(1:4)='TASK'
        IF (IMPFIL(10:10)     .EQ. '5') RUN(1:4)='AMBL'
        IF (IMPFIL(10:10)     .EQ. '6') RUN(1:4)='    '
        IF (IMPFIL(10:10)     .EQ. '7') RUN(1:4)='VARD'
        IF (IMPFIL(10:10)     .EQ. '8') RUN(1:4)='DRUM'
        IF (IMPFIL(10:10)     .EQ. '9') RUN(1:4)='ZERO'

        CATFIL(1:1) = 'D'
        CATFIL(2:2) = 'Z'
        CATFIL(3:3) = '1'
        CATFIL(4:4) = ':'
        CATFIL(5:10)=IMPFIL(5:10)
9111    FORMAT(A2)
9112    FORMAT( I2)
        CATFIL(11:11) = '.'

C       ---------------
C       OPEN DATA FILES
C       ---------------

        TYPE 500,CLEANS
40      TYPE 9113
9113    FORMAT(/////////////////' PLEASE INSERT DATA FLOPPY WITH AT
     1 LEAST 60 CONTIGUOUS FREE BLOCKS'/' INTO DRIVES DZ1 & DZ2.',
     1 ' WHEN READY, PRESS RETURN',/////////)
        ACCEPT 10,ITEMP
10      FORMAT(I5)
C
9510    CONTINUE
C
        CATFIL(12:12) = 'I'
        CATFIL(13:13) = 'M'
        CATFIL(14:14) = 'P'
        IREC=0
        CALL ERRSNS
        OPEN (UNIT=1, TYPE='OLD', NAME=CATFIL, FORM='FORMATTED',
     1 ERR=45                )
        GOTO 100
45      CONTINUE
```

```
      CALL ERRSNS (IERNUM)
      IF(IERNUM.EQ.29) THEN
      OPEN (UNIT=1, TYPE='NEW', NAME=CATFIL, FORM='FORMATTED',
     1 ERR=40                 )
      ELSE
      GOTO 40
      END IF
100   CONTINUE
C
C     ---------------------------------
C     STORE KEY FIELD INFO TO DATA FILE
C     ---------------------------------

D     TYPE *, 'EPOCHS, RUN DURATION (MINUTES)= ',IMINS,MIN
      WRITE(1,9120) EXP,(GROUP(I),I=1,8),(RUN          ),
     1  RUNNUM,(DIRECT(I),I=1,2),IDAY,NSN,(OSN(I),I=1,2),
     2  AGE,SUSC,SEX,(DATE(I),I=1,7),TESTIM,PREHR,PRETEM,PRESYS,PREDIA,
     3   PSTHR,PSTTEM,PSTSYS,PSTDIA,MIN,PRETST,
     4  MIN-PRETST-PSTTST,PSTTST,NUMDIA, 1  , 8    ,DIAG(1)

9120  FORMAT(  A1,X,8A1,X, A4,X,I2,X,2A1,2(X,I2),X,2A1,X,I2,X,I1,
     1 X,A1,X,7A1,X,I4,X,I3,X,I4,X,I3,X,I3,
     2  X,I3,X,I4,5(X,I3),5(X,I2))

      DO 9130 I = 2,14
         WRITE(1,9140) DIAG(I)
9130  CONTINUE
9140  FORMAT(109X,I2)

      WRITE(1,9150) DIAG(15),MAXREC
9150  FORMAT(109X,I2,  I3)

      FRMT(2) = '0'
      FRMT(3) = '6'
      ZERO = 0.0
      IERR=0
9650  CONTINUE
      IREC=IREC+1
      IF(IREC.GT.MAXREC) GOTO 9165
D     TYPE *,' IREC= ',IREC,' MAXREC= ',MAXREC
      CALL DRECT (IREC,IERR,IMPFIL)
      IF(IERR.EQ.1) GOTO 9160
      WRITE(1,9550) MEAN,0.,0.,0.,0.,SD,0.,0.,0.,0.
C     WRITE(1,9550) (DATCAR(I,1),I=1,4),0.,0.,0.,0.,
C    1  (DATCAR(I,2),I=1,4),0.,0.,0.,0.
9550     FORMAT(8(X,F9.4))
      GOTO 9650
9160  CONTINUE
      WRITE(1,9550) 0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.
      GOTO 9650
9165  CONTINUE
      CLOSE(UNIT=1)
      CATFIL(12:12)='C'
C     DATFIL(13)='A'
```

```
C       CATFIL(14)='L'
C       OPEN (UNIT=1, TYPE='NEW', NAME=CATFIL, FORM='FORMATTED',
C     1 ERR=40                  )
C       DO 9700 I=1,3
C       WRITE(1,9600) HIGH(I,2),HIGH(I,1),CALVAL(1,I),CALVAL(2,I)
C9600    FORMAT(  2(X, I10),2(X,F10.4))
C9700    CONTINUE
C       CLOSE(UNIT=1)
        IF(IFLAG.EQ.0) GOTO 9875
        CATFIL(13:13)='O'
        CATFIL(14:14)='M'
        OPEN (UNIT=1, TYPE='NEW', NAME=CATFIL, FORM='FORMATTED',
     1 ERR=40                  )
        OPEN (UNIT=2, TYPE='OLD', NAME='SY:TEMP.COM', FORM='FORMATTED',
     1 READONLY                )
        REWIND 2
        J=0
        KCNT=80
9750  CONTINUE
        J=J-KCNT
        IF(J.GT.KCHAR) KCNT=KCHAR-J+KCNT
        READ(2,9800) (CMT(I),I=1,KCNT)
        WRITE(1,9801)(CMT(I),I=1,KCNT)
9800    FORMAT(80A1)
9801    FORMAT(X,80A1)
        IF(J.GE.KCHAR) GOTO 9850
        GOTO 9750
9850    CONTINUE
        CLOSE(UNIT=1)
        CLOSE(UNIT=2)
9875    CONTINUE
         IF(N.EQ.2) GOTO 99990
         N=2
         CATFIL(3:3)='2'
         GOTO 9510
99990     CONTINUE
         TYPE *,' ARE YOU FINISHED WITH THE DIGITIZED DATA ?[Y/N] '
         ACCEPT 10000,ANS
10000    FORMAT(A1)
         IF(ANS.EQ.'Y') THEN
         TYPE *,' THEN YOU WANT TO DELETE THE DIGITIZED FILE ?[Y/N]'
         ACCEPT 10000,ANS
         IF(ANS.EQ.'Y') THEN
         OPEN (UNIT=2,NAME=IMPFIL           ,TYPE='OLD')
         CLOSE (UNIT=2,DISPOSE='DELETE')
         IMPFIL(11:14)='.DIG'
         OPEN (UNIT=2,NAME=IMPFIL           ,TYPE='OLD')
         CLOSE (UNIT=2,DISPOSE='DELETE')
         END IF
         END IF
         IF(IFLAG.EQ.1) THEN
         OPEN (UNIT=2,NAME='SY:TEMP.COM',TYPE='OLD')
         CLOSE (UNIT=2,DISPOSE='DELETE')
         END IF
```

```
C     OPEN (UNIT=1,STATUS='OLD',NAME='DW1:NUDRAW.TEL',FORM='FORMATTED')
C       CLOSE(UNIT=1,DISPOSE='DELETE')
        TYPE 91100
91100   FORMAT (/' SUCCESSFUL COMPLETION ')
99999   CONTINUE
        RETURN
        END
        SUBROUTINE DRECT (TCOUNT,IERR,IMPFIL)
C       STORAGE SEQUENCE AS FOLLOWS:
C       FIRST - RAW RESPIRATION
C       SECOND - DELTA Z
C       THIRD - DZ/DT
C       FOURTH - ECG

c       TKB FOR TASK BUILD
C
c       TKB>FILENAME=FILENAME
C       TKB>/
C       TKB>MAXBUF=1600
C       TKB>//
c

        PARAMETER (IFREQ=200)
C       integer buf(4*IFREQ,1)
        INTEGER tcount
C       DIMENSION X(15*IFREQ),Y(15*IFREQ)
        DIMENSION DATCAR(4,2)
        COMMON DATCAR
C       EQUIVALENCE (DATCAR,BUF)
        CHARACTER*14 IMPFIL

        OPEN (UNIT=2, status='old', NAME=IMPFIL           ,
     1       FORM='UNFORMATTED', access='direct',recl=8  )

C       do 100 tcount = 1,2
                read(2,REC=TCOUNT,ERR=990)((DATCAR(I,J),I=1,4),J=1,2)
C               TYPE *,'OK ON READ'
C               do 200 i = 1, 200
C                       write(5,10)i,(BUF(ICOUNT,1),ICOUNT=(i-1)*4+1,i*4)
C200            continue
C               TYPE *,'OK ON WRITE'
100     continue
        GOTO 999
990     CONTINUE
        IERR=1
999     CLOSE(UNIT=2, STATUS='SAVE')
10      FORMAT(x,i3,4(2x,i4))
20      FORMAT(1X,I5)

        RETURN
        END
        PROGRAM    DRAWED
        PARAMETER (IFREQ=200) ! SET SAMPLING SIZE FOR DIGITIZED DATA
        DIMENSION ISTAT(2),IRES(75),OUTPUT(10,70),
```

```
     1  SLOPE(2),ENTRCP(2)
        CHARACTER*1 ANS
        CHARACTER*1 ICHRPK(2),IBUF,ISTOP,IREPET
        CHARACTER*4 EPOCH ,ETIME
        VIRTUAL IDATA(9000)
        DIMENSION Y(1450),X(1000),NCHAN(3),SMIN(3),SMAX(3),DATCAR(5,50),
     1  DATSD(4),IPAR(6)
        INTEGER*2 IRESP(IFREQ)
        CHARACTER*14 CATFIL
        INTEGER LPTS(3),IPEAKS(50),IOSB(2),CLEANS(2)
        BYTE I233,I73,I162,IHOME(4)
        CHARACTER*2 IPT,IPB
        COMMON /PLOT/X,Y
        EQUIVALENCE (DATCAR,Y(1201)),(Y(501),OUTPUT)
        DATA NCHAN/3,4,1/,SMIN/350.,150.,0.  /,SMAX/550.,350.,150./
        DATA LPTS/3   ,3   ,10 /,NSMFRQ/100/,NREC/15/,IREAD/"001000/
        DATA A/.01/,B/0./,C/0./,IBRAC/']'/,ICHAN/3/
        DATA IGATE/0/,IM/0/,I233/"233/,I73/"73/,I162/  "162/
        DATA IHOME/155,63,54,108/,CLEANS/27.99/
C       CALL GETADR(IPAR(1),IBUF) !GET START ADDR OF IBUF & STOR IN IPAR(1)
C       IPAR(2)=1 !SET TO BYTE SIZE OF IBUF
        TYPE 4000,CLEANS
4000    FORMAT(X,4A1)
        TYPE 4500
4500    FORMAT (10X,60('*'),/////,22X,' DATA REDUCTION & EDITING ',
     1  /////,10X,60('*'),////)
C
C       READ FILE CONTAINING SLOPES, INTERCEPTS, C AND BSA
C              WHERE   C = RHO*L**2
C                      BSA = BODY SURFACE AREA
C

        OPEN (UNIT=1,NAME='DW1:NUDRAW.TEL',FORM='FORMATTED',TYPE='OLD')
        READ(1,2) SLOPE,ENTRCP,C,BSA,CATFIL,MAXREC
2       FORMAT(6(  G15.7),A14,I10)
        CLOSE (UNIT=1)

        IDZDT0=-ENTRCP(2)/SLOPE(2)! GET AD VALUE FOR DZDT=0
        IDZDT1=(1.-ENTRCP(2))/SLOPE(2)! GET AD VALUE FOR DZDT=1
100     CONTINUE

      TYPE *,' STARTING TIME CODE FOR DATA ON TAPE (eg. enter 300 for',
     1  ' 3:00)'
        ACCEPT *,ISTREC
        TYPE *, ' EPOCH FOR START OF DATA REDUCTION '
        ACCEPT *,ISTEPC
        TYPE *, ' ENTER LAST DATA EPOCH '
        ACCEPT *,IENEPC
C
C       KREC SETS THE STARTING RECORD FOR DATA IN DIGITIZED FILE
C       INDREC SETS THE ENDING RECORD FOR DATA IN DIGITIZED FILE
C       IDKREC SETS THE 15 SECOND EPOCH NUMBER (DISPLAYED TO SCREEN)
C               AND USED TO STORE RESULTS IN 15 SEC EPOCHS
C
```

```
          KREC= (ISTEPC-1)*15+61
          INDREC=(IENEPC)*15+61
          MAXREC=(INDREC-61)/15
          IDKREC=ISTEPC
          CATFIL(11:14)='.DIG'

 105      CONTINUE
 C        CALL QIO(IREAD,7,4,,IOSB,IPAR,IDSW)
 10       CONTINUE
          XMIN=0.
          XMAX=IFREQ *NREC
          CALL CGL( 90) !INITIALIZE GRAPHICS
          CALL CGL( 92) !NEW FRAME
          CALL CGL(103,'DW1:FILE2.GID',13) !INITIALIZE PLOT FILE
          CALL CGL(105,'DW1:FILE2.GID',13) !SELECT PLOT FILE
          CALL CGL( 80,XMIN,XMAX,0.      ,600.    ) !SET WINDOW TO DEFAULT VALUES
          CALL CGL(86,0) !SET ORIGIN
          OPEN (UNIT=', status='old', NAME=CATFIL, !OPEN DIGITIZED DATA FILE
      1        FORM='UNFORMATTED', access='direct',recl=4*IFREQ)
 C        DO 125 I=1,NREC
 C        IREC=KREC+I-1
 C
 C      read(1,REC=IREC,ERR=999)((IDATA(J+(I-1)*IFREQ),ID,ID,ID),
 C     1  J=1,IFREQ)
 125      CONTINUE
 C998      CLOSE(UNIT=1, STATUS='SAVE')
 C        M=0
 C        NPTS=LPTS(3)
 C        DO 135 L=1,IFREQ*NREC,NPTS
 C        M=M+1
 C        X(M)=L
 C        Y(M)=IDATA(L)
 C135      CONTINUE
          M=0 !SET COUNTER OF RESPIRATION VALUES
          IFRQRC=IFREQ*NREC !SET AREA SIZE FOR DIG (IDATA)BLOCKS
          DO 150 I=1,NREC
          IREC=KREC+I-1

 C        STORAGE SEQUENCE OF DIGITIZED DATA AS FOLLOWS:
 C        FIRST - RAW RESPIRATION - STORED IN RESP FROM 1 TO IFREQ
 C        SECOND - DELTA Z - STORED IN IDATA FROM 1 TO IFRQRC
 C        THIRD - DZ/DT - STORED IN IDATA FROM 1+IFRQRC TO 2*IFRQRC
 C        FOURTH - ECG - STORED IN IDATA FROM 1+2*IFRQRC TO 3*IFRQRC

        read(1,REC=IREC  ,ERR=999)((IRESP(J)          ,
      1 IDATA(J+(I-1)*IFREQ),IDATA(IFRQRC+J+(I-1)*IFREQ),
      2 IDATA(2*IFRQRC+ J+(I-1)*IFREQ)),J=1,IFREQ)

 C        PRINT *,(IECG(J+(I-1)*IFREQ ),J=1,IFREQ),J,I
 C
 C        STORE A SUBSET( EVERY LPTS(3) VALUE) OF RESP IN Y FOR PLOTTING
 C
          DO 175 J=1,IFREQ,LPTS(3)
          M=M+1
```

```
        Y(M)=IRESP(J)
175     CONTINUE
150     CONTINUE
999     CLOSE(UNIT=1, STATUS='SAVE') !CLOSE DIG. DATA FILE
C
C       PLOT FIRST RESPIRATION(K=3) THEN ECG(K=2) AND LAST DZ/DT(K=1)
C
        DO 3000 K=3,1,-1
        YSMIN=SMIN(K) !PARTITION SCREEN AREA MIN FOR K PLOT
        YSMAX=SMAX(K) !PARTITION SCREEN AREA MAX FOR K PLOT
        NPTS=LPTS(K)
C       ---------------------------------------
C       SET PLOT ARRAY PAIRS (X,Y)
C       ---------------------------------------
        IF(K.EQ.3) THEN
        DO 275 L=1,M !SETUP X VALUES FOR RESPIRATION PLOTTING
        X(L)=1+(L-1)*NPTS
275     CONTINUE
        ELSE
        M=0
        DO 300 L=1,IFREQ *NREC,NPTS !SETUP (X,Y) PAIRS FOR ECG AND DZ/DT PLOT
        M=M+1
        X(M)=L
        Y(M)=IDATA(IFRQRC*K+L)
300     CONTINUE
        END IF
        CALL INDEX(XMIN,XMAX,YMIN,YMAX,M    ) !DETERMINE PLOT LIMITS
        IF(K.EQ.1) THEN
        IF(IDZDT1-IDZDT0.LT.(YMAX-YMIN)/3) THEN !REDONE LIMITS IF NEEDED
        YMAX=IDZDT1+IDZDT1-IDZDT0
        YMIN=IDZDT0-(IDZDT1-IDZDT0)
        END IF
        IF(IDZDT1.GT.YMAX) YMAX=IDZDT1
        DZDT0=(IDZDT0-YMIN)/(YMAX-YMIN)*(YSMAX-YSMIN)+YSMIN !SCALE DZDT0
        DZDT1=(IDZDT1-YMIN)/(YMAX-YMIN)*(YSMAX-YSMIN)+YSMIN !SCALE DZDT1
C
C       PLOT DZ/DT CALIBRATION VALUES FOR OBSERVATION
C
        CALL CGL(    1,X(1), DZDT0) !MOVE "PEN" TO POSITION
        CALL CGL(    4,XMAX, DZDT0) !DRAW TO POSITION
        CALL CGL(    1,X(1), DZDT1) !MOVE "PEN" TO POSITION
        CALL CGL(    4,XMAX, DZDT1) !DRAW TO POSITION
        END IF
C       DO 322 L=1,10
C       TYPE *,X(L),Y(L),YMIN,YMAX,L
C       Y(L)=(Y(L)-YMIN)/(YMAX-YMIN)*(YSMAX-YSMIN)+YSMIN
C       TYPE *,X(L),Y(L),YMIN,YMAX,L
C322     CONTINUE
        DO 325 L=1,M !SCALE Y
C       PRINT *,X(L),Y(L),YMIN,YMAX,L
        Y(L)=(Y(L)-YMIN)/(YMAX-YMIN)*(YSMAX-YSMIN)+YSMIN
C       TYPE *,X(L),Y(L),YMIN,YMAX,L
325     CONTINUE
C       FACT=5./32767.
```

```
        CALL CGL(    1,X(1), Y(1)) !MOVE PEN TO POSITION
C       XOLD=X(600)+1./200.
C       NY=NREC*IFREQ
        NYPLT=IFRQRC  /NPTS
        CALL CGL(6,X,Y,NYPLT) !PLOT NYPLT X,Y PAIRS
        IF (K.EQ.1) THEN !PLOT EPOCH NUMBER AND START TIME OF EPOCH
        IEPOCH=IMOD(KREC-61,60)+(KREC-61)/60*100+ISTREC
        ENCODE (4,32500,ETIME)IEPOCH
        ENCODE (4,32500,EPOCH)IDKREC
32500   FORMAT(I4)
        CALL CGL (1,XMIN,SMIN(1))
        CALL CGL (16,EPOCH,4)
        CALL CGL (1,XMIN+240.,SMIN(1))
        CALL CGL (16,ETIME,4)
        END IF
500     CONTINUE
3000    CONTINUE !END OF PLOTTING
C
C       NEXT CALL PEAK DETECTION
C
D       OPEN (UNIT=2,STATUS='NEW',NAME='DW1:IMPTEMP.TST',
D    1  FORM='FORMATTED',ACCESS='SEQUENTIAL')
        CALL VOL(IFRQRC,NPEAKS,IDATA,IADMIN,IGATE,IM,IDZDT0,IDZDT1)
C       IDZDT - INPUT OF DZ/DT DATA
C       IFRQRC - NUMBER OF DZ/DT DATA POINTS
C       OUTPUT(3,I) - ARRAY CONTAINING TIME VALUES FOR DETECTED PEAKS
C       NPEAKS - NUMBER OF PEAKS DETECTED
        IF(NPEAKS.GT.0)THEN
        CALL CGL(12,4,0,0) !SET LINE STYLE TO DOTTED
C
C       PLOT PEAK INDICATORS
C
        DO 680 I=1,NPEAKS
        YLOW=SMIN(3)+40
        XL=(OUTPUT(3,I)-1.)
        CALL CGL(1,XL,SMAX(1)  ) !POSITION TO X=XL,Y=SMAX(1)
        CALL CGL(4, XL,YLOW) !DRAW LINE TO X=XL,Y=YLOW
        ENCODE (2,610,ICHRPK),I
610     FORMAT( I2)
        XLOW=XL-10.
        DO 620 J=1,2
        CALL CGL(1,XLOW,YLOW )
        CALL CGL(16,ICHRPK(J),1) !WRITE PEAK NUMBER J
        YLOW=YLOW-20.
620     CONTINUE
680     CONTINUE
        CALL CGL(12,1,0,0) !RESET LINE STLYE TO SOLID
C
C       USE A SUBROUTINE HERE TO CALCULATE THE TIME WHEN
C       dZ/dT=0 BEFORE EACH PEAK ALSO CALCULATE STROKE VOLUME
C
        CALL TFACT(NPEAKS,IFREQ ,C,NY    ,K,TYMEAN,
     1  SLOPE,ENTRCP,BSA,IDATA,KREC,IDZDT0,IADMIN,CATFIL,IDKREC)
C       ELSE
```

```
C       SET MEAN AND SD TO ZERO
        END IF
C       IF(ICOUNT.GT.1) THEN
C       CALL CGL(12,4,0,0)
C       DO 700 I=1,ICOUNT-1
C       XL=600.*I/200.
C       CALL CGL(1,XL,YMAX      )
C       CALL CGL(4,XL    ,YMIN      )
C700     CONTINUE
D       CLOSE(UNIT=2)
C
C       SET UP ONE LINE DIALOG AREA NOW
C
        L20=49
        L24=49
        WRITE(5,40000) I233,L20,I73.L24,I162
40000   FORMAT(1X,5A1)
        DO 725 I=1,50 !ZERO ALL IPEAKS - ARRAY OF USER SELECTED PEAKS
        IPEAKS(I)=0
725     CONTINUE
C
C       QUIRY EVENT FLAG 4 TO SEE IF USER REQUEST MADE
C
C       CALL READEF(4,IEF)
C       IF(IEF.GT.0) THEN ! REQUEST MADE VIA KEYBOARD
C       END IF
C       CALL QIO("12,7) ! CANCEL QUE I/O REQUEST

C
C       DIALOG SECTION
C
        TYPE *,' SKIP THIS EPOCH ? [ENTER Y/N]'
        ACCEPT 10000,ANS
        IF(ANS.EQ.'Y') THEN
        KREC=KREC+NREC !INCREMENT RECORD INDEX
        MAXREC=MAXREC-1 !REDUCE MAX RECORD SIZE BY ONE
        CALL CGL(106,'DW1:FILE2.GID',13) !DESELECT PLOT FILE
        CALL CGL(104,'DW1:FILE2.GID',13) !TERMINATE PLOT FILE
        CLOSE (UNIT=1,DISPOSE='DELETE')
        IF (KREC.GE.INDREC) GOTO 99999
        GOTO 105
        END IF
        TYPE *,' REDO ANALYSIS ? [ENTER Y/N]'
        ACCEPT 10000,ANS
        IF(ANS.EQ.'Y') THEN
        TYPE *,' ENTER GATE FACTOR, MINIMUM DIFFERENCE FACTOR NOW'
        ACCEPT *,IGATE,IM
        CALL CGL(106,'DW1:FILE2.GID',13)
        CALL CGL(104,'DW1:FILE2.GID',13)
        CLOSE (UNIT=1,DISPOSE='DELETE')
        GOTO 10
        END IF
        TYPE *,' OK TO CALCULATE HEATHER INDEX ? [Y/N]'
        ACCEPT 10000,ANS
```

```
        IF(ANS.EQ.'Y' ) THEN
        CALL HICALC(NPEAKS,IFREQ ,IDATA       ,KREC,NREC,CATFIL)
        ELSE
        DO 7250 I=1,NPEAKS
        DATCAR(4,I)=0.0
 7250   CONTINUE
        END IF
        CALL CGL(106,'DW1:FILE2.GID',13)
        CALL CGL(104,'DW1:FILE2.GID',13)
        CALL CGL(93,INAM,ICODE) !REPORT ERROR
        IF(ICODE.NE.0) THEN
        TYPE *,' INAM= ',INAM,' ICODE= ',ICODE
        CALL CGL( 91) !TERMINATE GRAPHICS
        END IF
 7025   CONTINUE
        CALL ERRSNS
 C      PRINT *,' NPEAKS= ',NPEAKS
 C      PRINT *, (IPEAKS(II),II=1,NPEAKS)
        TYPE *,' LIST SELECTED PEAKS NOW (SEPERATE W/ COMMA )'
        READ(5,7725) (IPEAKS(I),I=1,NPEAKS)
 7725   FORMAT(<NPEAKS>I3)
 730    CONTINUE
 740    CONTINUE
 C      PRINT *,' NPEAKS= ',NPEAKS
 C      PRINT *, (IPEAKS(II),II=1,NPEAKS)
        KPEAKS=0
        DO 750 I=1,NPEAKS !DETERMINE NUMBER OF PEAKS SELECTED
        IF(IPEAKS(I).EQ.0) GO TO 775
        KPEAKS=KPEAKS+1
 750    CONTINUE
 775    CONTINUE
 C      TYPE *, ' KPEAKS= ',KPEAKS ,(IPEAKS(I),I=1,KPEAKS)
        IF(KPEAKS.GT.0) THEN
 C    PRINT *,IDKREC,( IPEAKS(I),(DATCAR(K,IPEAKS(I)),K=1,4),I=1,KPEAKS)
        CALL STRVOL(KPEAKS,DATSD,IPEAKS)
        ELSE !ZERO STROKE VALUE,CARDIAC OUTPUT,CARDIAC INDEX, HEATHER INDEX
        DO 810 I=1,4
        DATCAR(I,1)=0.0 !MEANS
        DATSD(I)=0.0 !STANDARD DEVIATIONS
 810    CONTINUE
        END IF
        CALL ERRSNS(IERR)
        IF(IERR.NE.0) GOTO 7025
 820    CONTINUE
 C
 C      WRITE RESULTS OF EPOCH(=IDKREC) CALCS TO INTERNAL FILE
 C
        CATFIL(11:14)='.IMP'
        OPEN (UNIT=1,STATUS='OLD',NAME=CATFIL,
     1  FORM='UNFORMATTED',ACCESS='DIRECT',RECL=8  )
        WRITE(1,REC=IDKREC) ((DATCAR(K,1),K=1,4)),DATSD
        CATFIL(11:14)='.DIG'
        CLOSE(UNIT=1)
        CLOSE(UNIT=2)
```

```
      TYPE *,' DO YOU WANT A COPY ? [Y/N]'
      ACCEPT 10000,ANS
10000 FORMAT(A1)
      IF (ANS.EQ.'Y') THEN
      IRES(1)=1
      CALL CPRNT(ISTAT,IRES,'DW1:FILE2.GID',13)
      ELSE
      OPEN (UNIT=1,STATUS='OLD',NAME='DW1:FILE2.GID')
      CLOSE (UNIT=1,DISPOSE='DELETE')
      END IF
      TYPE *,' EXIT ? [Y/N]'
      ACCEPT 10000,ANS
      IF(ANS.EQ.'Y') GOTO 99999
      IDKREC=IDKREC+1 !INDEX EPOCH COUNTER FOR PLOT AND RESULTS FILE
      KREC=KREC+NREC !INDEX DIGITIZED DATA FILE RECORD COUNTER
      IF(KREC.GE.INDREC) GOTO 99999 !AT END OF DATA FILE YET
      GOTO 105
99999 CONTINUE
      TYPE 4000,CLEANS
      OPEN (UNIT=1,NAME='DW1:NUDRAW.TEL',FORM='FORMATTED',TYPE='OLD')
      WRITE(1,2) SLOPE,ENTRCP,C,BSA,CATFIL,MAXREC !RECORD MAXREC VALUE
      CLOSE (UNIT=1)
C     WRITE(5,40000) I233,I73,I162
C     TYPE *,' EXST CALLED ',' ISTAT= ',ISTAT
      CALL EXST(ISTAT) !SET FLAG FOR EXIT TO PARENT TASK
      STOP
      END
      SUBROUTINE INDEX (XMIN,XMAX,YMIN,YMAX,NPTS)
      PARAMETER (IFREQ=200)
      DIMENSION X(1000),Y(1450)
      COMMON /PLOT/X,Y
C     PRINT *,K,NPTS,(Y(I),I=1,NPTS)
      SX=639./NPTS
      YMIN=Y(1)
      YMAX=YMIN
      DO 300 I=1,NPTS
C     PRINT *,Y(I),I
      IF(Y(I).LT.YMIN) YMIN=Y(I)
      IF(Y(I).GT.YMAX) YMAX=Y(I)
300   CONTINUE
C     SY=479./(IYMAX-IYMIN)
C     ENY=-479.*IYMIN/(IYMAX-IYMIN)
      XMIN=0.
      XMAX=X(NPTS     )
C     PRINT *,Y,YMIN,YMAX,NPTS
      RETURN
      END
      SUBROUTINE VOL(NY,KPEAKS,IY,IADMIN,IGATE,IM,IDZDT0,IDZDT1)
C     DO PEAK DETECTION USING DIGITAL ROUTINE 'PEAK'
      PARAMETER (IFREQ=200)
      VIRTUAL IY   (9000     )
      DIMENSION INPUT(15*IFREQ)
      DIMENSION OUTPUT(10,70)
      DIMENSION ITABLE(68),VTYPE(2,2)
```

```
      INTEGER BUF(  IFREQ,1)
      DIMENSION  Y(1450)
      COMMON /PLOT/IX(2000), Y
      EQUIVALENCE (IX,INPUT),(OUTPUT,Y(501))
      DATA VTYPE/'  VA','LLEY','BASE','LINE'/

      DATA ITABLE/1, 5,  5,800  ,1,0,0,61*0/
      DATA INLAST,IDIMO/600,70/
      CALL ERRSET(112,.TRUE.,.FALSE.,.FALSE.,.FALSE.,)
      DZREF=IDZDT0+(IDZDT1-IDZDT0)*.5
C     TYPE  *,' HERE IN VOL ',NY,IY
C
C     SET TABLE VALUES FOR DIGITAL PEAK DETECTION ROUTINE
C
C     ITABLE(6)=0
      ITABLE(7)=0
      INPTR=0
      INLAST=NY
      NPEAKS=0
      ITABLE(3)=2 !SET GATE FACTOR
      ITABLE(4)=100 !SET MIN DIFFERENCE FACTOR
      IF(IGATE.NE.0) THEN !RESET IGATE AND IM IF REQUESTED BY USER
      ITABLE(3)=IGATE
      ITABLE(4)=IM
      END IF
C
C     TRANSCRIBE DZDT DATA TO ARRAY INPUT
C
C     N=0
      DO 1000 I=1,NY
      INPUT(I)=IY(3000+I)
C     TYPE  *,I,INPUT(I),IY(I)
 1000  CONTINUE
C     IADMIN=-16000
      IADMIN=IMIN(INPUT,NY )
C     OPEN (UNIT=2,TYPE='NEW',NAME='INPUT.DAT',FORM='FORMATTED')
C     WRITE (2,1980) (INPUT(I),I=1,NY)
C1980  FORMAT(8I10)
C     CLOSE (UNIT=2)
      IF(IADMIN.LT.0) THEN !OFFSET INPUT VALUES SO ALL ARE NON NEGATIVE
      DO 2000 I=1,NY
      INPUT(I)=INPUT(I)-IADMIN
 2000  CONTINUE
      END IF
C     TYPE *,     (INPUT (I  )      ,I=1,NY    ) ,IADMIN
C     WRITE(2,*) ((  INPUT (I  )) ,I=1,NY  ) ,IADMIN,SLOPE,INTRCP
C
C     CALL ROUTINE TO FIND PEAKS AND TRAILING MINS TIMES
C     FOR dZ/dT MIN=PEAKS HEIGHT AND T=TIME AT TRAILING
C     MINS - TIME WHEN dZ/dT=0 BEFORE PEAKS
C     OUTPUT ARRAY CONTAINS RESULTS OF PEAK DETECTION
C
      CALL PEAK(ITABLE,INPUT,INLAST,INPTR,OUTPUT,IDIMO,NPEAKS)
C     TYPE *,NPEAKS,INLAST,INPTR
```

```
C
C       NEXT SECTION NEEDED BECAUSE PEAK ROUTINE MAY AVERAGE INPUT FOR PEAKS
C
        DO 2500 I=1,NPEAKS
        OUTPUT(2,I)=INPUT(IFIX(OUTPUT(3,I)))
2500    CONTINUE

        IF(IADMIN.LT.0) THEN !CONVERT RESULTS IF DATA OFFSET
        DO 3000 I=1,NPEAKS
        OUTPUT(2,I)=OUTPUT(2,I)+IADMIN
        OUTPUT(4,I)=OUTPUT(4,I)+IADMIN
        OUTPUT(7,I)=OUTPUT(7,I)+IADMIN
3000    CONTINUE
        END IF
C
C       REFINE PEAKS BASED ON SOME CRITERION IF NECESSARY
C
        KPEAKS=0
        DO 4000 I=1,NPEAKS
        IF(OUTPUT(2,I).LE.DZREF) GOTO 4000
        KPEAKS=KPEAKS +1
        IF(KPEAKS.EQ.I) GOTO 4000
        DO 3500 J=1,10
        OUTPUT(J,KPEAKS)=OUTPUT(J,I)
3500    CONTINUE
4000    CONTINUE
D       WRITE (2,  *  ) NPEAKS,INLAST,INPTR
D       WRITE (2,20000)
C       WRITE (1 ,20000)
20000   FORMAT(' PEAK NO.',8X,'AREA',4X,'P HEIGHT',6X,'P TIME',4X,
     A  'L HEIGHT',6X,'L TIME',/,11X,'HALF WIDTH',4X,'T HEIGHT',6X,
     B  'T TIME',8X,'TYPE',8X,'RATE'//)
        DO 4 L=1,NPEAKS
        KK=OUTPUT(9,L)+1
D      WRITE(2, 30000)(L,(OUTPUT(I,L),I=1,8),(VTYPE(M,KK),M=1,2),
D     1  OUTPUT(10,L))
C      WRITE(1 , 30000)(L,(OUTPUT(I,L),I=1,8),(VTYPE(M,KK),M=1,2),
C     1  OUTPUT(10,L))
30000   FORMAT(I9,5F12.0,/,9X,3F12.0,4X,2A4,F12.0)
 4       CONTINUE
        RETURN
        END
         FUNCTION IMIN (INPUT,ICOUNT)
         DIMENSION INPUT(ICOUNT)
         IMIN=INPUT(1)
         DO 1000 I=2,ICOUNT
         IF(INPUT(I).LT. IMIN) THEN
         IMIN=INPUT(I)
         END IF
 1000    CONTINUE
         RETURN
         END
        SUBROUTINE TFACT (NPEAKS,IFREQ,C,INLAST,K,TYMEAN,
     1  SLOPE,INTRCP,BSA,IZO,IREC,IDZDTO,IADMIN,CATFIL,IDKREC)
```

```
      PARAMETER (JFREQ=200)
      PARAMETER (NREC=15  )
      PARAMETER (NUM=220)
      DIMENSION IEPC(NUM),ZOEPC(NUM)
      DIMENSION INPUT(15*JFREQ),OUTPUT(10,70),DATCAR(5,50)
      VIRTUAL IZO(9000    )
      COMMON /PLOT/X(1000),Y(1450)
      REAL SLOPE(2),INTRCP(2)
      CHARACTER*14 CATFIL
      EQUIVALENCE(Y(501),OUTPUT),(X,INPUT),(DATCAR,Y(1201))
      LOGICAL*1 TYMEAN
      DATA ICOUNT/0/
      DATA IEPC/ 1,2,3,4,
     15,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,
     125,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,
     146,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,
     167,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,
     1 87, 88, 89, 90, 91, 92, 93, 94, 95 ,96, 97, 98, 99,100,101,102,
     1103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,
     *119,120,121,122,123,124,125,126,127,128,129,130,131,132,133,134,
     2135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,
     3151,152,153,154,155,156,157,158,159,160,161,162,163,164,165,
     4166,167,168,169,170,171,172,173,174,175,176,177,178,179,180,
     5181,182,183,184,185,186,187,188,189,190,191,192,193,194,195,
     6196,197,198,199,200,201,202,203,204,205,206,207,208,209,210,
     7211,212,213,214,215,216,217,218,219,220/
      DATA ZOEPC/20.9,21.0,21.0,21.0,20.9,21.0,21.0,20.9,20.9,20.9,21.0,
     1      21.0,21.0,21.0,21.0,21.0,21.0,21.0,21.0,21.0,20.9,21.0,
     1 21.0,20.9,20.9,21.0,21.0,20.9,20.9,20.9,20.9,20.9,20.9,20.9,20.9,
     2 20.9,21.0,21.0,21.1,22.4,22.4,21.3,21.1,21.2,21.2,21.2,21.2,21.2,
     3 21.3,21.2,21.2,21.2,21.2,21.5,21.3,21.2,21.3,21.4,21.3,21.2,21.3,
     4 21.3,21.3,21.3,21.4,21.3,21.5,22.2,22.2,21.4,21.1,21.3,21.2,21.1,
     5 21.1,21.2,21.2,21.2,21.2,21.3,21.2,21.3,21.3,21.3,21.2,21.3,21.3,
     6 21.3,21.4,21.4,21.3,21.3,21.3,21.4,21.2,21.2,21.1,21.1,21.1,21.0,
     1 21.0,
     7 21.1,21.0,21.2,21.3,21.3,21.3,21.3,21.4,21.2,21.3,21.5,21.3,21.4,
     8 21.3,21.4,21.5,21.4,21.4,21.5,21.5,21.3,21.2,21.2,21.1,21.2,21.1,
     9 21.1,21.1,21.1,21.1,21.4,21.4,21.4,21.3,21.5,21.3,21.3,21.3,21.5,
     1 21.4,
     1 21.4,21.4,21.5,21.3,21.3,21.3,21.3,21.7,21.3,21.1,21.1,21.7,21.9,
     1 21.3,21.3,21.1,21.8,21.1,21.2,21.3,21.1,21.0,21.2,21.2,21.2,21.2,
     1 21.2,21.2,21.2,21.3,21.3,21.3,21.3,21.1,21.2,21.2,21.3,21.3,21.1,
     1 21.1,21.3,21.2,21.7,21.7,21.2,21.2,21.2,21.1,21.2,21.2,21.2,21.2,
     1 21.5,21.3,21.5,21.2,21.3,21.3,21.2,21.2,21.3,21.1,21.2,21.2,21.2,
     1 21.2,21.4,21.2,21.2,21.2,21.2,21.3,21.3,21.3,21.4,21.2,21.31.3/
      N=0
C     DO 200 I=1,NREC
C     KREC=IREC+I-1
C     PRINT *,IREC,KREC,N,NREC
C     CALL DIRECT (KREC,CATFIL,2,I,IZO)
C     DO 150 J=1,IFREQ
C     N=N+1
C     IZO  (N)=ISPACE(J        ,1)
150   CONTINUE
```

```
 300      CONTINUE
          NDZDTO=IDZDTO
          IF(IADMIN.LT.0) NDZDTO=IDZDTO-IADMIN
C         DO 100 I=1,2
C         SLOPE(I)=1.
C         INTRCP(I)=1.
 100      CONTINUE
C         C=1.
C         BSA=1.
          DO 1000 I=1,NPEAKS
          ISTRT=OUTPUT(3,I)
          DO 400 J=ISTRT,2,-1
          IF(INPUT(J).GT.NDZDTO  ) GOTO 400
          TSTRT= J
          GOTO 500
 400      CONTINUE
          TSTRT=0
C         HIT THE BEGINNING OF THE GROUP BUT STILL GOING DOWN; CHECK
C         IPTOLD FOR STARTING TIME
C         ISTRT=170
C425      CONTINUE
C         IF(ICOUNT.GT.1) THEN
C         DO 450 J=ISTRT,2,-1
C         IF(IPTOLD(J-1).LT.IPTOLD(J) ) GOTO 450
C         TSTRT=600.*(ICOUNT-1)-(170.-J+1)
C         GOTO 500
C450      CONTINUE
D         TYPE *, ' ERROR NO BOTTOM '
C         END IF
C         TSTRT=600.*(ICOUNT-1)
 500      CONTINUE
          TIME=(OUTPUT(8,I  )-TSTRT)
C         CALL CGL(37,3,0)
          CALL CGL(33,TSTRT,350.)
C         CALL CGL(37,5,0)
          CALL CGL(33,OUTPUT(8,I),350.)
          ZNOT=IZO(  ISTRT              )*SLOPE(1)+INTRCP(1)
C         DO 550 J=1,NUM
C         IF(IDKREC.EQ.IEPC(J)) THEN
C         ZNOT=ZOEPC(J)
C         GOTO 575
C         ENDIF
 550      CONTINUE
 575      CONTINUE
          DZDT=OUTPUT(2,I)*SLOPE(2)+INTRCP(2)
          VNTVOL=C*TIME*(DZDT                                  )/IFREQ/ZNOT**2
          DATCAR(1,I)=VNTVOL
          IF(I.EQ.1) THEN
          BPM=IFREQ*60./(OUTPUT(3,2)-OUTPUT(3,1))
          ELSE
          BPM=IFREQ*60./(OUTPUT(3,I)-OUTPUT(3,I-1))
          END IF
C         ELSE
C         END IF
```

```
      CO=VNTVOL*BPM/1000.
      CI=CO/BSA
C     HI=0.0
      DATCAR(2,I)=CO
      DATCAR(3,I)=CI
      DATCAR(4,I)=DZDT
      DATCAR(5,I)=OUTPUT(3,I)
C
C      SAVE TIME FACTORS FOR HI FROM DZDT DATA AND DZDT PEAK VALUES
C            WHERE HI = DATCAR(4,I)/[Q-DATCAR(5,I)]
C                    AND Q IS TIME OF Q WAVE BEFORE DZDT PEAK
C
D     WRITE(2,*       ) OUTPUT(2,I),TIME,VNTVOL,TSTRT,J,ISTRT,
D    1 ZNOT,C,DZDT,BPM,SLOPE,INTRCP,IZO(ISTRT)
D     WRITE(2,*       )(OUTPUT(3,I)-1.)/IFREQ,VNTVOL,CO,CI,HI,
D    1 TIME/IFREQ,DZDT,BPM,ZNOT,C
C     PRINT *,I,TIME,' ( ',OUTPUT(8,I), TSTRT,' ) ',ZNOT,
C    1 ' ( ',OUTPUT(3,I),' ) ',DZDT,' ( ',OUTPUT(2,I),' )'
 600   CONTINUE
 1000  CONTINUE
C     OLDOUT=OUTPUT(3,NPEAKS)
C     DO 4000 J=431,600
C     IPTOLD(J-430)=INPUT(J)
C4000  CONTINUE
      RETURN
      END
      SUBROUTINE STRVOL (KPEAKS,DATSD,IPEAKS)
      PARAMETER (IFREQ=200)
      DIMENSION DATCAR(5,50),DATSD(4),IPEAKS(KPEAKS)
      COMMON /PLOT/X(1000),Y(1450)
      EQUIVALENCE (DATCAR,Y(1201))
      DO 1500 I=1,4
      SUM=0.0
      SUMSQ=0.0
      DO 1000 J=1,KPEAKS
      SUM=SUM+DATCAR(I,IPEAKS(J))
      SUMSQ=SUMSQ+DATCAR(I,IPEAKS(J))**2
1000  CONTINUE
      DATCAR(I,1)=SUM/KPEAKS
      DATSD(I)=SQRT(KPEAKS*SUMSQ-SUM*SUM)/KPEAKS
1500  CONTINUE
      RETURN
      END
      SUBROUTINE HICALC (NPEAKS,IFREQ,IECG,KREC,NREC,CATFIL)
      PARAMETER (JFREQ=200)
      VIRTUAL IECG(9000    )
      DIMENSION OUTPUT(10,70),DATCAR(5,50),INPUT(15*JFREQ)
      CHARACTER*14 CATFIL
      COMMON /PLOT/X(1000),Y(1450)
      EQUIVALENCE (Y(501),OUTPUT),(Y(1201),DATCAR),(X,INPUT)
      N=0
C     DO 200 I=1,NREC
C     IREC=KREC+I-1
C     TYPE *,CATFIL
```

```
C       CALL DIRECT (IREC,CATFIL,N,I,IECG)
C       DO 150 J=1,IFREQ
C       N=N+1
C       IECG (N)=ISPACE( J       ,1)
150     CONTINUE
200     CONTINUE
        DO 1000 I=1,NPEAKS
        IEND=DATCAR(5,I)
        IF(I.NE.1) THEN
        ISTRT=(IEND+DATCAR(5,I-1))/2
        ELSE
        ISTRT=(1+IEND)/2
        END IF
        ICOUNT=IEND-ISTRT+1
        DO 500 J=1,ICOUNT
        INPUT(J)=IECG(ISTRT+J-1+6000)
500     CONTINUE
        ITIME=ISTRT+IMAX(INPUT,ICOUNT)-1
        TIME=ITIME
        CALL CCL(33,TIME,150.)
        TIME=(DATCAR(5,I)-TIME)/IFREQ
        IF(TIME) 600,600,700
600     CONTINUE
        DATCAR(4,I)=0.0
        GOTO 1000
700     CONTINUE
        DATCAR(4,I)=DATCAR(4,I)/TIME
1000    CONTINUE
        RETURN
        END
        FUNCTION IMAX(INPUT,ICOUNT)
        DIMENSION INPUT(ICOUNT)
        IMAX=ICOUNT
        DO 1000 I=ICOUNT-1,1,-1
        IF(INPUT(I).GT.INPUT(IMAX)) THEN
        IMAX=I
        END IF
1000    CONTINUE
        RETURN
        END
```

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16. Abstract

This report contains the source code and documentation for a computer program used to process impedance cardiography data. The cardiodynamic measures derived from impedance cardiography are ventricular stroke volume, cardiac output, cardiac index and Heather index. The program digitizes data collected from the Minnesota Impedance Cardiograph, electrocardiography (ECG), and respiratory cycles and then stores these data on hard disk. It computes the cardiodynamic functions using interactive graphics and stores the means and standard deviations of each 15-sec data epoch on floppy disk. This software was designed on a Digital PRO380 microcomputer and used version 2.0 of P/OS, with (minimally) a 4-channel 16 bit analog/digital (A/D) converter. Applications software is written in Fortran 77, and uses Digital's Pro-tool Kit Real Time Interface Library (PRTIL), CORE Graphic Library (CGL), and laboratory routines. Source code can be readily modified to accommodate alternative detection, A/D Conversion and interactive graphics. The object code utilizing overlays and multitasking has a maximum of 50 Kbytes.

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